A Geologic Guide To NORTH CAROLINA'S STATE PARKS

NORTH CAROLINA GEOLOGICAL SURVEY

GEOLOGIC TIME SCALE FOR NORTH CAROLINA

EON	ERA	PERIOD	EPOCH	GEOLOGIC EVENTS IN NORTH CAROLINA	AGE*
PHANEROZOIC	CENOZOIC	Quaternary	Recent	Deposition of sediments in Coastal Plain. Erosion of Piedmont and Appalachian Mountains to their present rugged features.	
			Pleistocene		1.7
		Tertiary	Pliocene		5
			Miocene	Phosphate deposited in eastern North Carolina (Beaufort and Pamlico Counties).	24
			Oligocene	Limestone deposited in Coastal Plain. Weathering and erosion continue in Piedmont and Mountains.	
			Eocene		
			Paleocene		66
	MESOZOIC	Cretaceous	Late	Deposition of estuarine and marine sediments in the Coastal Plain. Continued erosion of the Piedmont and Mountains.	
			Early	Sediments deposited in northern half of the Coastal Plain. Cape Fear Arch begins to develop. Piedmont and Mountains eroded.	138
		Jurassic	Late	Marine sediments deposited on outer continental shelf. Piedmont and mountains eroded.	
			Middle		
			Early	Weathering and erosion of the Blue Ridge and the Piedmont areas. Emplacement of diabase dikes and sheets.	205
		Triassic	Late	Faulting and rifting creates Deep River, Dan River, and Davie basins. Basins fill with continental clastic sediments known as "red beds".	
			Middle	Formation of the Atlantic Ocean as North America and Africa drifted apart. Weathering and erosion of Piedmont and Mountains.	
			Early		240
	PALEOZOIC	Permian		Final collision of North America and Africa.Thrust faulting in west; deformation in eastern Piedmont.	290
		Pennsylvanian		Emplacement of igneous intrusions — Time of uplift and erosion.	330
		Mississippian		Emplacement of igneous intrusions — Time of uplift and erosion.	360
		Devonian		Emplacement of igneous intrusions — Emplacement of lithium, mica, and feldspar-rich pegmatites, primarily in the Kings Mountain and Spruce Pine districts. Metamorphism of Carolina slate belt. Period of erosion.	410
		Silurian		Emplacement of igneous intrusions — Period of uplift and erosion.	435
		Ordovician		Emplacement of igneous intrusions — Continental collision and beginning of mountain building process--faulting, folding, and metamorphism of pre-existing rocks.	500
		Cambrian		Emplacement of igneous intrusions — Sandstone, shale, and limestone deposited in the mountain area. Continued deposition of Carolina slate belt rocks. Gold deposits of the slate belt form	570
PROTEROZOIC	PRECAMBRIAN	Late		Sedimentary and volcanic rocks deposited in the mountains and Piedmont. Local intrusions of igneous rocks.	900
		Middle		Sedimentary, volcanic, and igneous rocks formed in the Blue Ridge and metamorphosed to gneisses and schists.	1600
		Early		Oldest dated rock in North Carolina is 1,800 million years old.	2500
				Oldest known rock in U.S. is 3,600 million years. Oldest known rocks in world are 3,850 million years. Formation of the Earth was 4,500 million years ago.	

* Estimated age in millions of years.

A GEOLOGIC GUIDE TO

NORTH CAROLINA'S STATE PARKS

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Edited by
P. Albert Carpenter, III

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A Geologic Guide To North Carolina's State Parks

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A Geologic Guide To North Carolina's State Parks

INTRODUCTION

Geology is something most of us do not think about as we go about our daily activities. Yet, all of us are affected by the powerful geologic processes that formed our continent — creating varied minerals and rocks; concentrating minerals into mineable ore deposits; eroding and sculpting landscape — eventually resulting in the beautiful State we enjoy today.

North Carolina extends across three major physiographic provinces: the Coastal Plain, the Piedmont, and the Blue Ridge. These three provinces provide a diversity of landscapes and seascapes. They include the barrier islands and swampy areas on the Coast, the rolling Piedmont with its occasional prominent monadnocks, and the towering peaks of the Blue Ridge Mountains. Within the three physiographic provinces, the rocks are grouped into belts of similar rocks. The Blue Ridge Province includes the Blue Ridge belt; the Piedmont Province includes the Triassic basins, the Inner Piedmont, Kings Mountain, Milton, Charlotte, Carolina slate, Raleigh, and Eastern slate belts; and the Coastal Plain Province includes rocks of the Coastal Plain and Sandhills area.

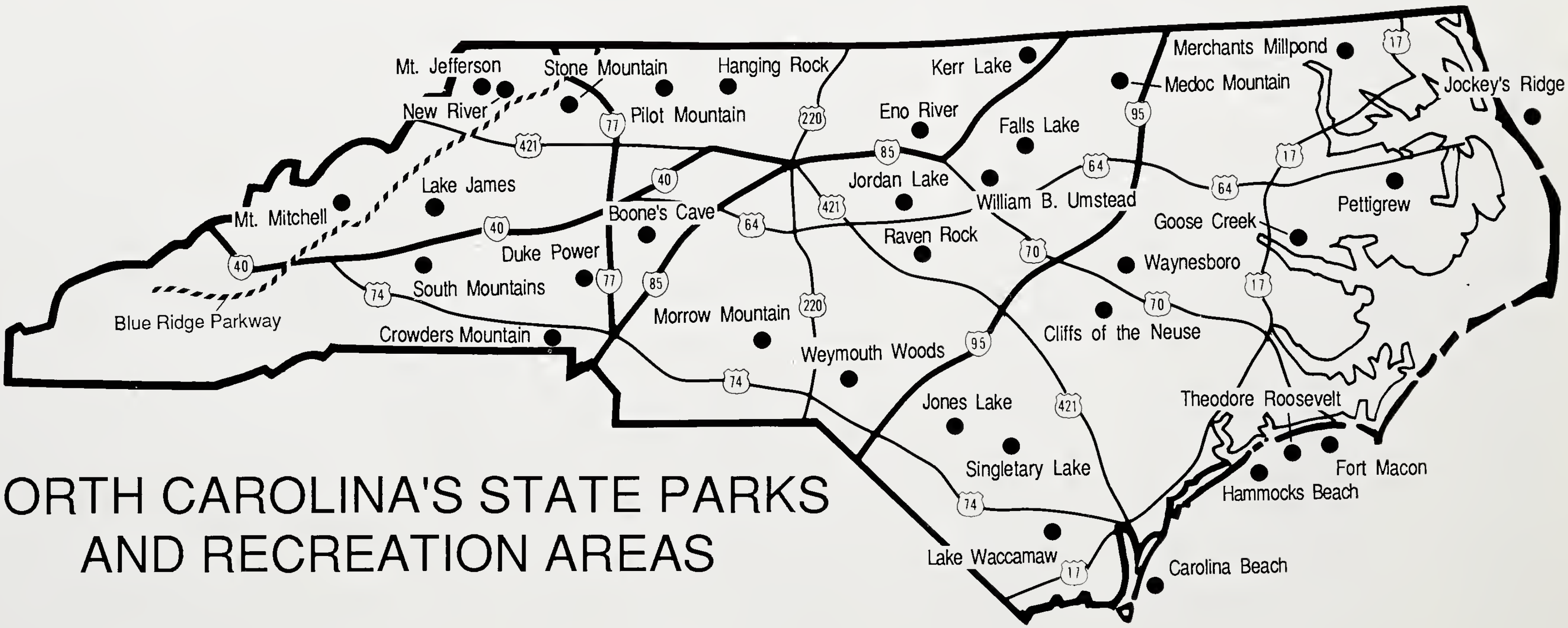
The varied geology is reflected in the diversity of parks in the state park system (see table, page 4). Eastern coastal parks and recreation areas include beach and sound environments like those of Carolina Beach, Fort Fisher, Fort Macon, Goose Creek, Hammocks Beach, Jockey's Ridge, and Theodore Roosevelt. Coastal Plain parks such as Cliffs of the Neuse, Jones Lake, Lake Waccamaw, Merchants Millpond, Pettigrew, Singletary Lake, Waynesboro, and Weymouth Woods showcase the Sandhills, Carolina Bays, and other coastal environments. Piedmont parks and recreation areas such as Boone's Cave, Duke Power, Eno River, Falls Lake, Kerr Lake, Medoc Mountain, Morrow Mountain, Raven Rock, and William B. Umstead are characteristic of the rolling Piedmont and Fall Line areas. The western Piedmont and Mountain parks of Crowders Mountain, Hanging Rock, Lake James, Mount Jefferson, Mount Mitchell, New River, Pilot Mountain, South Mountains, and Stone Mountain, display the more spectacular, rugged terrains of those areas.

Geology influences almost everything on the Earth. The hardness and structure of rocks influence the landscape of our state. Rocks erode and weather to form soil, and thus, control the type of vegetation we see in an area and the crops we grow. Minerals provide us with raw materials to build cities, power cars, and heat homes.

North Carolina has an unequaled variety of minerals. The discovery of a 17 pound gold nugget in Cabarrus County, in 1799, was the first discovery of gold in North America. Today, rockhounds enjoy looking for emeralds, rubies, and sapphires at commercial mineral collecting sites. Large mines and quarries yield valuable minerals, such as spodumene, phosphate, feldspar, mica, olivine, and pyrophyllite, that make North Carolina an important contributor to the Nation's mineral supply. Gold continues to attract amateur prospectors as well as major exploration companies.

North Carolina contains all three major rock types: igneous, metamorphic, and sedimentary. Some rocks are as old as one billion years, but others are only a few million years old. Some formed in the warm, calm waters of a shallow sea; others formed by heat and pressure deep in the Earth's crust. Still others were blasted fiery hot from now extinct volcanoes.

Through the park system, North Carolina has showcased for its citizens a portion of the state's natural beauty. Protected from the attack of bulldozers and the desire of man to mold nature into his own image, the state parks are safe havens in a rapidly changing environment. Here, we are free to wander the trails, absorb the natural beauty, and



NORTH CAROLINA'S STATE PARKS AND RECREATION AREAS

reflect on the complex geologic processes that are in evidence around us.

The Earth changes constantly. As new rocks form, they are heated and cooled, folded and faulted, and go through the slow processes of gradual uplift and exposure at the surface. Here they weather and erode and are washed into rivers and ocean basins as sediments. These processes, continuing today, are visible around us. As you walk the park trails, think about the changes the rocks have undergone to reach their present form. Rocks on top of Hanging Rock and Pilot Mountains were once sediments under the sea. Rocks in Eno River and Morrow Mountain State Parks were once blasted out of volcanoes. What processes shaped the Carolina Bays of Jones Lake, Lake Waccamaw, Pettigrew, and Singletary Lakes? In another million years, how will nature have changed these areas? How will man's influence change what nature created?

This guide is intended to increase your enjoyment of the state parks and to help you become more aware of the complex geology of our State. It will enable you to discover, first hand, the geologic principles you can only read about in textbooks. The geologic names used in this guide also appear on the 1985 ***Geologic Map of North Carolina.*** The ***Geologic Map of North Carolina*** and this publication provide background for understanding the geology of the State's 33 parks and recreation areas, many of which are centered on outstanding geologic features.

In many parks, there are trails too numerous to describe here. Many of these trails also reveal interesting geologic features but are less traveled by park visitors. Maps available in each state park show the additional trails.

While enjoying your visit to the state parks, please leave the rocks for others to enjoy. Rock, mineral, and fossil collecting in state parks is not allowed by State law.

Additional information on the geology and mineral resources of North Carolina is available from the North Carolina Geological Survey Section, P.O. Box 27687, Raleigh, N.C. 27611; phone (919) 733-2423.

NORTH CAROLINA STATE PARKS

Park	Geologic Setting	Geologic Province	Major Geologic Points Of Interest
COASTAL PLAIN			
Carolina Beach	Coast	Coastal Plain	Dunes, sinkholes
Cliffs of the Neuse	River bank	Coastal Plain	Cliffs, fossils
Fort Macon	Barrier island	Coastal Plain	Beach stabilization, dunes, salt marsh
Goose Creek	Tidewater	Coastal Plain	Swamp, salt marsh
Hammocks Beach	Barrier island	Coastal Plain	Dunes, salt marsh, wave-cut scarp
Jockey's Ridge	Barrier island	Coastal Plain	Dunes
Jones Lake	Carolina bay	Coastal Plain	Carolina bay
Lake Waccamaw	Carolina bay	Coastal Plain	Carolina bay, fossils, peat
Merchants Millpond	Millpond	Coastal Plain	Surface sands
Pettigrew	Carolina bay	Coastal Plain	Carolina bay, peat
Theodore Roosevelt	Barrier island	Coastal Plain	Maritime forest, salt marsh
Singletary Lake	Carolina bay	Coastal Plain	Carolina bay
Waynesboro	River	Coastal Plain	River, floodplain
Weymouth Woods	Sandhills	Coastal Plain	Sandhills
PIEDMONT			
Boone's Cave	River	Charlotte belt	Cave, porphyritic granite
Crowders Mountain	Monadnock	Kings Mtn. belt	Kyanite, metasedimentary and metavolcanic rocks, monadnock
Duke Power	Lake	Kings Mtn. belt	Exfoliation, metamorphic rocks
Eno River	River	Carolina slate belt	Metavolcanic rocks, rapids
Falls Lake	Lake	Raleigh belt-Triassic	Igneous, metamorphic, and sedimentary rocks
Hanging Rock	Monadnock	Inner Piedmont	Monadnock, cliffs, cross-bedding, spheroidal weathering, waterfalls
Jordan Lake	Lake	Traissic basin	Triassic sedimentary rocks
Kerr Lake	Lake	Raleigh belt-Carolina slate belt	Fault zone, metamorphic rocks
Lake James	Lake	Inner Piedmont	Metamorphic rocks
Medoc Mountain	Fall line	Eastern slate belt	Gravel bar, joints, igneous and metamorphic rocks, molybdenite
Morrow Mountain	Uwharrie Mtns.	Carolina slate belt	Bedding, flow banding, metavolcanic rocks
Pilot Mountain	Monadnock	Inner Piedmont	Cliffs, cross-bedding, inselberg, spheroidal weathering
Raven Rock	Fall line	Eastern slate belt-Raleigh belt	Cliff, joints, metamorphic rocks, rapids, river terraces, quartz veins
South Mountains	Foothills	Inner Piedmont	Cave, debris slide, metamorphic rocks, waterfalls
William B. Umstead	Piedmont	Raleigh belt	Igneous and metamorphic rocks, joints
MOUNTAIN			
Mt. Jefferson	Mountain	Blue Ridge belt	Mountain, metamorphic rocks, vistas
Mt. Mitchell	Mountain	Blue Ridge belt	Metamorphic rocks, mountain, vistas
New River	River	Blue Ridge belt	Igneous and metamorphic rocks, rapids, cliffs
Stone Mountain	Monadnock	Inner Piedmont	Exfoliation sheets, igneous and metamorphic rocks, joints, monadnock, water falls, weathering pits, xenolith

GENERAL GEOLOGY

From the Blue Ridge and Great Smoky Mountains to the white sandy beaches of the Atlantic Ocean, the "Tar Heel" state has a variety of natural resources awaiting the traveler. North Carolina's state parks are a showcase for the many geologic features in the State. The parks provide opportunities to explore the wonders of nature in a natural, unspoiled setting.

North Carolina has a long and complex geologic history. Although much remains to be learned, detailed geologic studies provide a general understanding of regional geological relationships. The state is best described in terms of geological belts; that is, areas with similar rock types and geologic history.

Blue Ridge Belt: This mountainous region is composed of rocks from over one billion to about one-half billion years old. This complex mixture of granite, gneiss, volcanic, and sedimentary rock has repeatedly been squeezed, fractured, faulted, and twisted into folds. The Blue Ridge Belt is well known for its deposits of feldspar, mica, and quartz—basic materials used in the ceramic, paint, and electronic industries.

Inner Piedmont Belt: The Inner Piedmont belt is the most intensely deformed and metamorphosed segment of the Piedmont. These rocks are about 500-750 million years old. They include gneiss, schist, and granitic rock. The northeast-trending Brevard Fault zone forms much of the boundary between the Blue Ridge and Inner Piedmont belts. Although this zone of strongly deformed rocks is one of the major structural features in the southern Appalachians, its origin is poorly understood. Crushed stone for road aggregate and building construction is the principal commodity produced.

Kings Mountain Belt: The belt consists of less intensely deformed and metamorphosed volcanic and sedimentary rocks. The rocks are about 400-500 million years old. World-famous lithium deposits are mined here. Lithium is used in ceramics, aluminum production, greases, and medicine.

Milton Belt: This belt consists of gneiss, schist, and metamorphosed intrusive rocks. The principal mineral resource is crushed stone for road aggregate and for building construction.

Charlotte Belt: The belt consists mostly of igneous (rock crystallized from molten magma) rocks such as granite, diorite, and gabbro. These are 300-500 million years old.

Carolina Slate Belt: This belt consists of heated and deformed volcanic and sedimentary rocks. It was the site of a series of oceanic volcanic islands about 550-650 million years ago. This belt is known for its numerous abandoned gold mines and prospects. North Carolina led the nation in gold production before the California Gold Rush of 1849. In recent decades, only minor gold mining has taken place but mining companies continue to show interest in the area. Mineral production today is crushed stone and pyrophyllite which is used in refractory applications, insecticide carriers, wallboard, and latex foam fillers.

Triassic Basins: These basins are filled with sedimentary rocks that formed about 200-190 million years ago. Streams carried mud, silt, sand, and gravel from adjacent highlands into rift valleys similiar to those of Africa today. The shales are mined and processed to make brick. North Carolina leads the nation in brick production.

Raleigh Belt: The Raleigh Belt contains granite, gneiss, and schist. In the 19th century, there were a number of small building stone quarries in this region, but today the main mineral product is crushed stone for construction. In the 1980's, the value of crushed stone produced in North Carolina exceeded $100,000,000 per year. For all mineral resources mined in North Carolina, the average return per acre devoted to mining yearly is over $20,000.

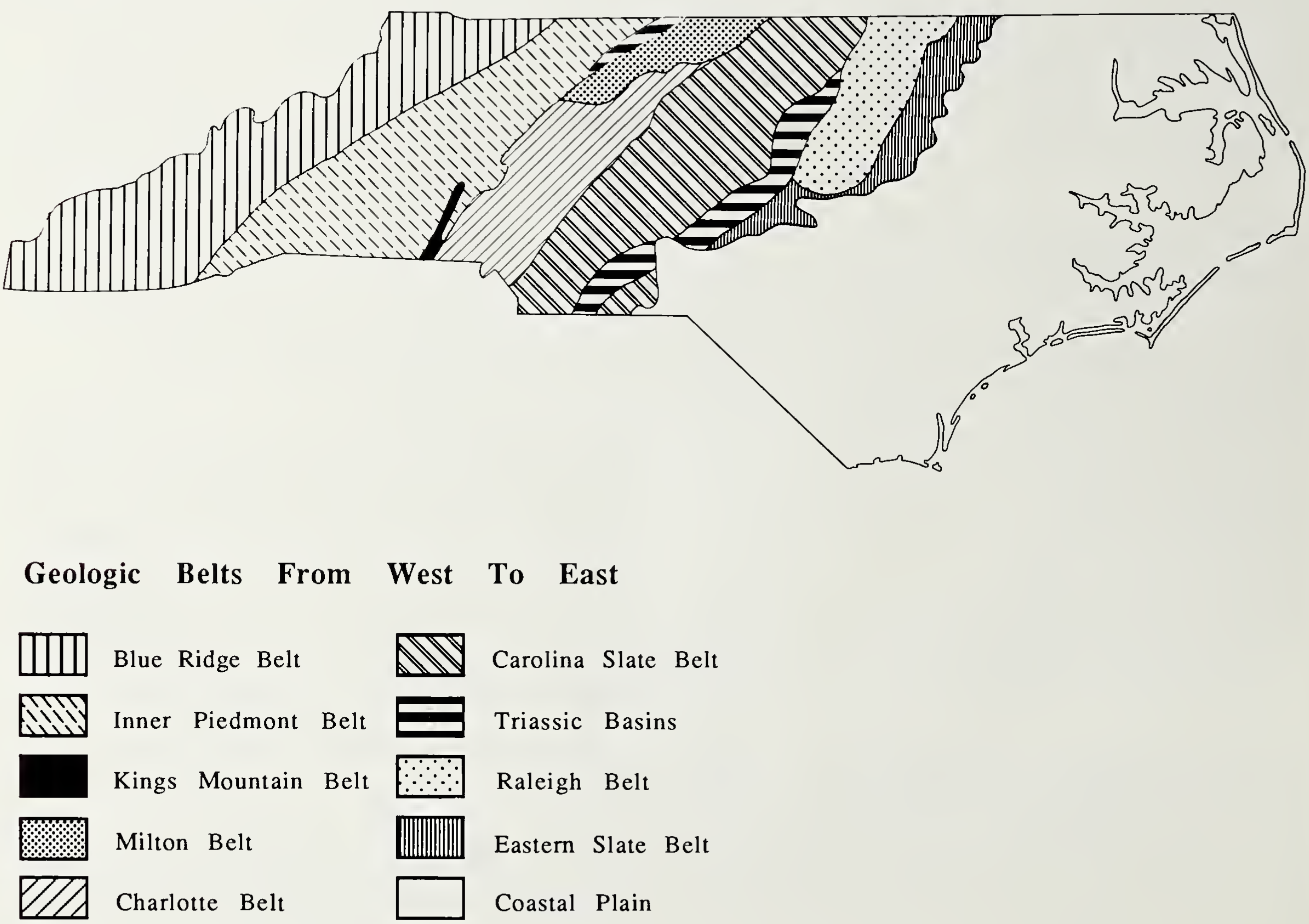
Eastern Slate Belt: This belt contains slightly metamorphosed volcanic and sedimentary rocks similar to those of the Carolina slate belt. The rocks are poorly exposed and partially covered by Coastal Plain sediments. The metamorphic rocks, 500-600 million years old, are intruded by younger, approximately 300 million year old, granitic bodies. Gold was once mined in the belt, and small occurrences of molybdenite, an ore of molybdenum, have been prospected here. Crushed stone, clay, sand, and gravel are currently mined in this belt.

Coastal Plain: This province is a wedge of mostly marine sedimentary rocks that gradually thickens to the east. The Coastal Plain is the largest geologic area of the state, covering about 44% of the land area. The most common rock types are sandstone and clay, although a significant body of limestone occurs in the southern part of the Coastal Plain. In the Coastal Plain, geology is best understood from studying data gathered from well drilling. The state's most important mineral resource in terms of dollar value is phosphate, an important fertilizer component, mined near Aurora, Beaufort County.

GEOLOGIC TIME SCALE

Geologists use a geologic time scale to compare the ages of rocks. ***Refer to the Geologic Time Scale inside the front cover.*** The oldest rocks are at the bottom of the chart, the younger rocks are at the top. The ages may be expressed as ***relative*** ages, based on fossil dating, stratigraphic position, and crosscutting relationships of intrusive rocks; or they may be expressed as ***absolute*** ages, based on isotopic dating (measuring the natural radioactive decay of a rock or mineral). The time of metamorphic events can be determined by measuring the radioactive isotopes of new minerals formed during metamorphism.

Twelve geologic periods have been established so geologists can easily refer to a distinct period of geologic history; for example, the ***Cambrian Period*** refers to the time from 500 million to about 570 million years ago. The names are used throughout this guide to help compare the ages of rocks in various parts of the state.



Coastal Parks

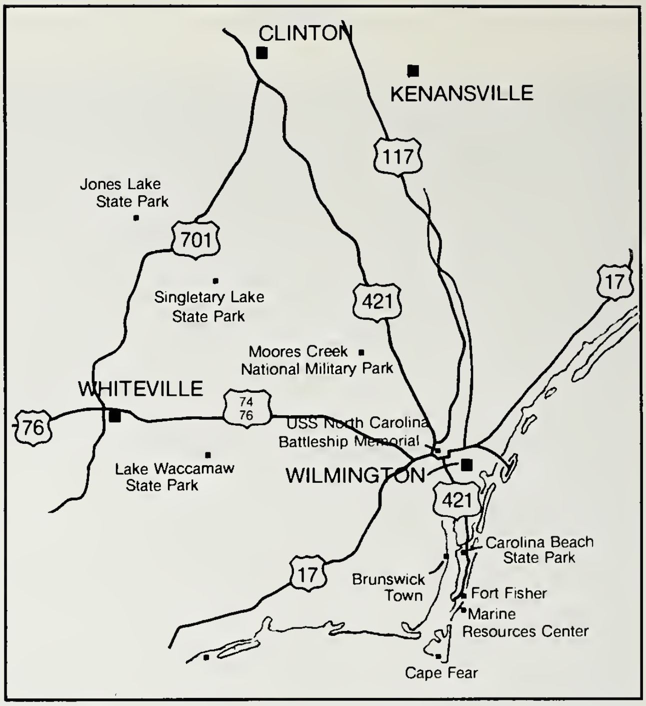
CAROLINA BEACH STATE PARK AND FORT FISHER RECREATION AREA

Carolina Beach State Park is located in New Hanover County south of Wilmington. Fort Fisher, a state historic site, is 6 miles south of Carolina Beach State Park, along US Highway 421.

REGIONAL GEOLOGY

The park is in the Coastal Plain physiographic province. The Coastal Plain is a wedge of marine and nonmarine sediments that gradually thickens toward the coast. The sediments are of Jurassic to Recent age (200 million to 10 thousand years old) and overlie the east-sloping crystalline basement. A thin layer of younger sand and clay blankets the older sediments. In the vicinity of Carolina Beach, roughly paralleling the course of the Cape Fear River, the crystalline basement is gently bowed upward along the ***Cape Fear Arch***, a prominent northwest-southeast trending structural feature. Sediments at Carolina Beach are approximately 1,530 feet thick; at Cape Hatteras the sediments are over 10,000 feet thick, illustrating how the thickness of the sediments increases away from the center of the arch.

The park is located on the east bank of the Cape Fear River on the Cape Fear Peninsula. The



northern boundary of the park is along ***Snow's Cut***, an artificial waterway excavated to create access between the Cape Fear River and the Intracoastal Waterway. Carolina Beach is a mainland beach but displays many features characteristic of barrier islands because of the narrow peninsula width. At the southernmost tip of the peninsula is ***Cape Fear***, one of 3 prominent capes along the North Carolina coast.

Coquina at Fort Fisher Recreation Area.

Three capes (***Cape Hatteras***, ***Cape Lookout***, and ***Cape Fear***) occur along the North Carolina coastline. The location of these capes may be controlled by a hard, cemented ***coquina*** that underlies portions of the inner shelf. The coquina, or "beachrock," was formed along an ancient Pleistocene shoreline that is now partially immersed. Examples of this coquina can be seen at Fort Fisher where it crops out along the beach and in the banks of Snow's Cut near Carolina Beach State Park. The action of the circular currents (eddies) spinning off the Gulf Stream may also contribute to the development of the cape features.

GEOLOGY

Along the shoreline at Carolina Beach, modern coastal processes erode the beaches in response to slowly rising sea level. The creation of the man-made Carolina Beach Inlet caused erosion rates to accelerate. The overall movement of sand along the coast is from north to south. It is carried by ***longshore currents***. Longshore currents flow parallel to the shoreline and are caused by waves that approach the coast at an angle. When a wave breaks, individual sand grains wash up on the beach in the ***swash zone*** and are carried back to sea in a zig-zag pattern. Creation of the artificial inlet cut the steady southerly sand supply to the beaches south of the inlet, literally "starving" the Cape Fear Peninsula of sand needed to maintain the beach.

On the western side of the peninsula are relict geomorphic features and sediments formed during the ***Pleistocene Epoch***. Carolina Beach State Park lies entirely within this western area of the peninsula.

TRAILS

The walking trail begins at the southeast corner of the marina parking lot. The trail follows the east bank of the Cape Fear River, crossing in and out of the salt marshes and along the sandy river banks. Salt marshes trap sediment and help stabilize the peninsula. Approximately one mile from the beginning of the trail is a large stabilized sand dune called ***Sugarloaf***. Sugarloaf attains a height of 55 feet above sea level. It is part of an east-west trending ridge of stabilized sand dunes of Pleistocene age. Sand dunes are ***eolian*** or "wind-blown" features. The east-west trend of these dunes reflects the ancient wind direction, and indicates that, during the Pleistocene, the predominant wind direction was different from the predominant wind direction today. Trees and grasses cover the dune. The fragile vegetation stabilizes the dune and protects it from the wind. Stabilized dunes protect beaches and barrier islands from erosion and are an important part of the beach profile.

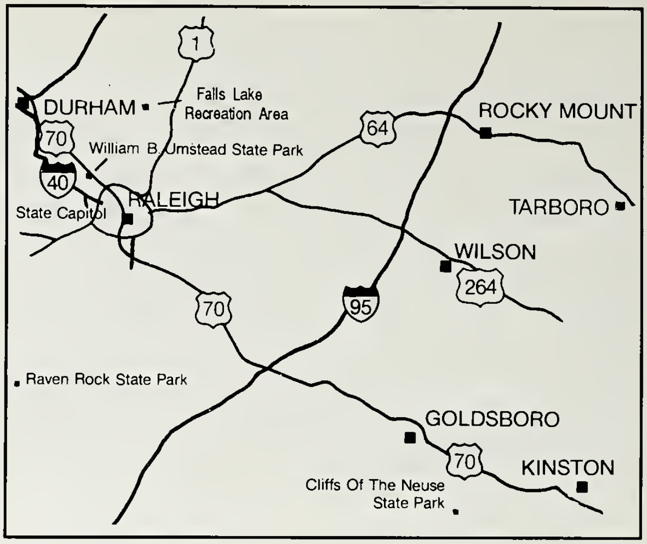
A series of small shallow ponds occur farther along the trail, north and east of the Sugarloaf sand dune. These ponds are ***sinkholes*** that formed in the Pleistocene ***coquina*** or ***shell limestone*** that underlies the park. Groundwater dissolves and weakens the limestone which then collapses to form sinkholes. Occasionally, sinkholes fill with water and become ponds.

Other geologic features of interest are found in nearby areas outside the park boundary. ***Fossils*** can be collected along the banks of Snow's Cut, just north of the park boundary. These fossils are described in North Carolina Geological Survey Bulletin 89, ***Fossil Collecting in North Carolina***. The same Pleistocene coquina that underlies the park can be seen along Snow's Cut. There it consists of a loose, unconsolidated sandy shell bed underlain by a hard, indurated crystalline coquina.

Outcrops of the same hard, indurated coquina occur along the northern end of ***Fort Fisher***. They form a low ledge exposed at low tide along the shoreline. It is the only natural outcrop of beach rock along the North Carolina coast. For that reason, it is listed as a ***Natural Heritage Site*** and collecting or defacing the outcrop is prohibited. The coquina outcrop created the eroded bluff upon which Fort Fisher is located. At Fort Fisher, the coquina beds disrupt the normal north to south movement of sand; the hard limestone ledge is resistant to erosion and slows the steady flow of sand grains along the shoreline. The interruption of sand movement creates an imbalance between sediment supply and the capacity of the waves to carry sand. This imbalance results in a slight increase in erosion north of the coquina beds, and the pronounced erosion south of the beds that creates the bluff at Fort Fisher. Attempts to reinforce the bluff with rip-rap (large boulders) only increase erosion rates along the coastline because the obstruction disrupts the steady transport of sediment.

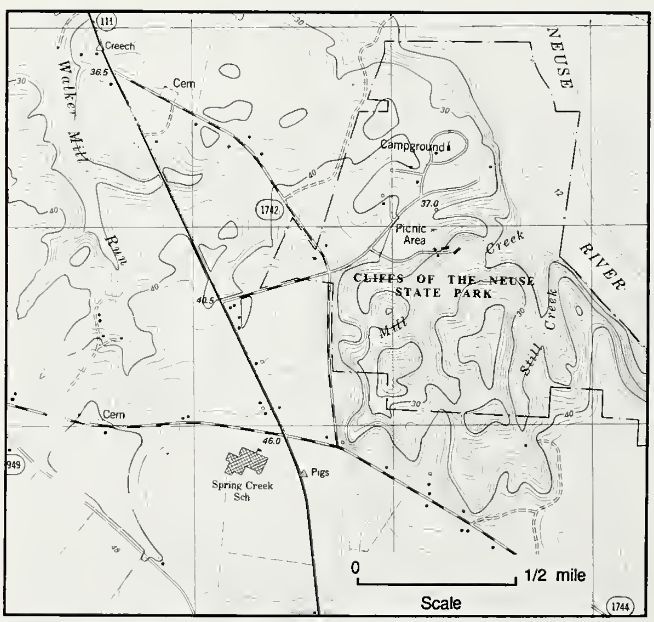
CLIFFS OF THE NEUSE STATE PARK

Cliffs of the Neuse State Park is located along the Neuse River in Wayne County, about 13 miles southeast of Goldsboro, near the community of Seven Springs. Approximately 600 acres in size, most of the park is on the southwest side of the river. The park is appropriately named for its most spectacular natural feature, a sheer cliff. The cliff, ranging up to 90 feet high, forms the river bank for much of the river's traverse through the park.



REGIONAL GEOLOGY

Cliffs of the Neuse lies within the Coastal Plain region of the state. This is an area of generally low-lying, flat to gently rolling topography that extends from the coast to the Piedmont. ***Sedimentary rocks*** such as sandstone, clay, and limestone underlie the Coastal Plain surface. These sediments dip slightly in a southeasterly direction and gradually thicken from a thin layer capping the hill tops at the ***fall line*** to nearly 10,000 feet thick at Cape Hatteras. They overlie steeply dipping folded and faulted ***crystalline rocks*** such as schist, gneiss, granite, and volcanic rocks similar to those that occur in the Piedmont. The Coastal Plain sedimentary rocks were deposited in a variety of marine to non-marine settings including shallow-shelf seas, rivers and floodplains, lagoons, marshes, estuaries, reefs, and dunes.



A topographic map shows the deeply dissected terrain.

The rocks of the Coastal Plain and their ***fossils*** tell a history of repeated advances and retreats of the sea. The advances and retreats occurred when the elevation of sea level rose or fell relative to the elevation of the land. Sea level changes may result from two major causes. One cause involves global forces whereby land masses and ocean basins develop and change. As an ocean opens and widens through processes called ***rifting*** and ***drifting***, sea level appears to drop. On the other hand, as a basin closes or as a new land mass forms, sea level appears to rise. Secondly, major climatic changes cause large amounts of sea water to be frozen or released from the Earth's polar ice caps generating changes in the elevation of sea level. These processes generally span tens- to hundreds-of-thousands-of-years.

GEOLOGY OF THE CLIFFS

The cliffs are composed of two main geologic units. The upper one is an unnamed ***surficial sand*** unit that contains white quartz pebbles in its lowermost part. This sand unit averages about 10 feet thick along the cliff. The pebbles stand out on the cliff face because the loose sand that surrounds them is easily knocked away by wind and rain. Eventually, pebbles break free, fall down the cliff face, and are swept into the river.

The lower unit is below the pebble zoneand extends for about 200 feet below river level. This is the ***Black Creek Formation*** of Late Cretaceous age (66-96 million years old). This formation is widespread within the North Carolina Coastal Plain. Extensive areas of outcrop occur in the Tar, Neuse, and Cape Fear River valleys.

On the cliff, the Black Creek Formation consists of a number of beds ranging from sandstone to clay, with most being a mixture of sand, silt, and clay. The clays are usually dark gray to black. The sands are yellowish to white, although in some places they are stained red and cemented with iron-oxide. The yellowish tint on the cliff is a surface coating of a ***sulfur compound***. The sulfur comes from the breakdown of organic material such as leaves, twigs, and wood fragments that were deposited with the sand and clay.

The Black Creek Formation in the park area is thought to have formed in a broad flat coastal zone. Certain environments in the coastal zone were habitats to specially adapted animals. Their remains sometimes were buried and preserved as fossils. They are found in the cliff today, weathering out much as the pebbles in the upper bed are weathering.

Parts of the modern day Louisiana and Mississippi gulf coastal zone resemble what existed in the Cliffs of the Neuse area during deposition of the Black Creek Formation. Within the cliffs are sediments probably deposited in a marsh. This is the dark clay bed near the top of the Black Creek Formation. Organic material is very abundant in this bed. Between clay layers are very thin layers of sand and silt that probably represent periodic flooding, perhaps associated with storm events or unusually high tides.

Sandy beds, like those in the lower part of the cliff, indicate an environment subjected to currents which swept away the finer-grained clay and silt. Some sort of channelized flow, perhaps in a wide and shallow tidal channel sweeping over the flat, may account for these deposits.

HIKING TRAILS

Spanish Moss Trail, Bird Trail, and Galax Trail have a combined distance of 1.75 miles. They wind up and down the hilly topography of the park adjacent to the Neuse River. Such topographic relief is unusual for the Coastal Plain as a whole, but not uncommon for areas that lie along the southwest sides of the major rivers and streams. These are usually the steepest drainages in the eastern part of the State.

Geologic exposures like those along the Neuse River are not present along the trails. Except on sheer cliffs or similar rapidly eroding areas, the Coastal Plain sediments are readily altered to soil, and vegetation takes hold. The soil also tends to "creep" slowly downslope and obscure any geologic exposures.

The ***Spanish Moss Trail*** starts at the interpretive center and loops down to the Neuse River floodplain before returning to the center. One steep slope or face near the junction of the loop of this trail exposes sandy sediments of the Black Creek Formation.

The ***Bird Trail*** follows the river for a short distance downstream from the cliffs overlook before turning up, across and back down Still Creek. Before its junction with Mill Creek, Still Creek cascades over a small series of iron-oxide cemented sandstone layers within the Black Creek Formation. These dark red (striped) rocks may be seen from the trail.

Galax Trail follows Mill Creek before looping back and merging with Bird Trail. Between Galax Trail and Mill Creek, limestone boulders containing molds and casts of shells are visible. Loose, white sand of the Black Creek Formation covers much of the middle portion of the trail. ***(Sample collecting in the park is prohibited).***

BARRIER ISLANDS

The Atlantic and Gulf Coast ***barrier island chain*** is the longest and best developed in the world. However, it is not unusual since similar island chains occur along nearly all gently sloping coasts. Their origin varies from region to region depending on the geologic history, the nature of ocean currents operating in the region, and the supply of sand available to the coastal system.

These islands lie seaward of bays, sounds, or lagoons and are often separated from each other by narrow channels called ***inlets***. Tides cause water to flow in and out of the shallow bodies of water behind the barrier islands through the inlets.

North Carolina's Outer Banks originated 10,000 to 12,000 years ago as coastal dunes when sea level was much lower than its present elevation. The shoreline was some 40 miles seaward of its present location. Since that time sea level has been rising. Initially, the sea level rise was quite rapid as continental glaciers retreated and supplied large amounts of water to the oceans. The rate has slowed over the last 5,000 years to an estimated one foot rise per century.

When sea level began to rise, it broke through low areas of the coastal dunes and flooded the low-lying area behind them. As sea level continued to rise, the barrier chain moved along with the migrating coast as the ocean-side material was constantly transported to the sound or lagoon side. Three main processes account for the transport of material from the ocean to the sound. One is the movement of sediment through inlets by the tide. On each tidal cycle the flood of water into the sound carries sand and mud, and deposits it much in the way a river builds a delta at its mouth. Hence, the term ***tidal delta*** is used to describe the deposits that form on the sound side of inlets. Inlets eventually migrate to another location or simply become choked with sediment, while a new inlet forms elsewhere and the tidal delta deposits become part of the barrier.

Sand dune migration is another process by which barrier islands grow in a landward direction. Onshore flowing breezes blow sand derived from the beach up and over the dune crests. In this manner they grow on the sound side and build steadily in a landward direction.

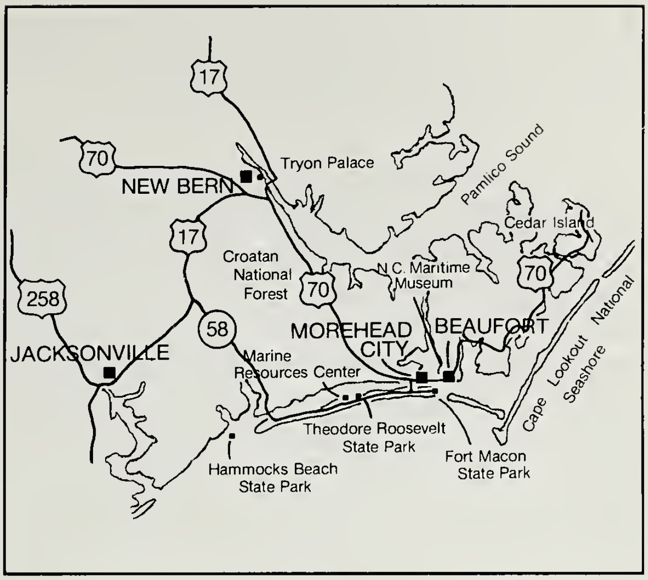
The third main process accounting for barrier island migration is ***overwash***. This is often a sudden event, usually associated with unusually high tides driven by storms. In overwash, the sea breaks through the dunes at a vulnerable point and a fan of sediment is deposited on the back side of the barrier. Sometimes the breach remains open as an inlet, but usually dunes reform in the low area.

Fort Macon, Hammocks Beach, and Jockey's Ridge are good parks in which to see barrier island processes.

Bear Island.

FORT MACON STATE PARK

Fort Macon State Park is located in Carteret County, east of the town of Atlantic Beach. The park is on the tip of a stretch of barrier islands called Bogue Banks. Beaufort Inlet forms the eastern park boundary. The port of Morehead City lies on the mainland across Bogue Sound.



BARRIER STABILIZATION

Barrier migration is a process common to all barrier islands. Migration of Bogue Banks is well evidenced by samples from boreholes drilled in the island. They show marsh and sound deposits underlying the present dune system. Sometimes winter storms expose the dark colored muddy salt marsh sediments when the pounding waves erode unusually large amounts of beach sand. Many of the shells found along the beach are fossils that waves washed up from several thousand-year-old lagoon deposits exposed on the ocean side of the barrier islands.

A sea level rise of one foot per century produces about 5 feet per year of shoreward barrier migration along Bogue Banks. Efforts to halt the natural process are evident in the park and its general vicinity. Most obvious is the massive stone ***jetty*** built to trap sand moving along the beach front and keep it from filling Beaufort Inlet. The jetty caused a build up of sand on the park side but erosion on the inlet side. The project is not 100% effective, but it helps to decrease the amount of expensive dredging required to keep the channel open.

Two major rock types were used to construct the jetty. One is limestone containing casts and molds of the hard parts of shell fish and other organisms that made up the original rock deposit. The other rock, granite, ranges from pink to gray in color. The limestone, which is 30-40 million years old, is young compared to the several hundred million-year-old granite. Both rock types were quarried inland and transported to the coast.

Several short jetty-like structures, called ***groins***, were built out from the shoreline in the park to help stabilize the beach. Groins, like jettys, are designed to trap sand moving along the beach.

Beach replenishment is also used in the effort to maintain the beaches of Bogue Banks. This process involves pumping dredge spoils from Beaufort Inlet onto the beach front to replace sand which was lost to erosion. Often the sand pumped onto the beach remains only temporarily because the added sand steepens the beach profile. This, in turn, accelerates erosion and the new material is gone in a few seasons.

BARRIER ISLAND ENVIRONMENTS

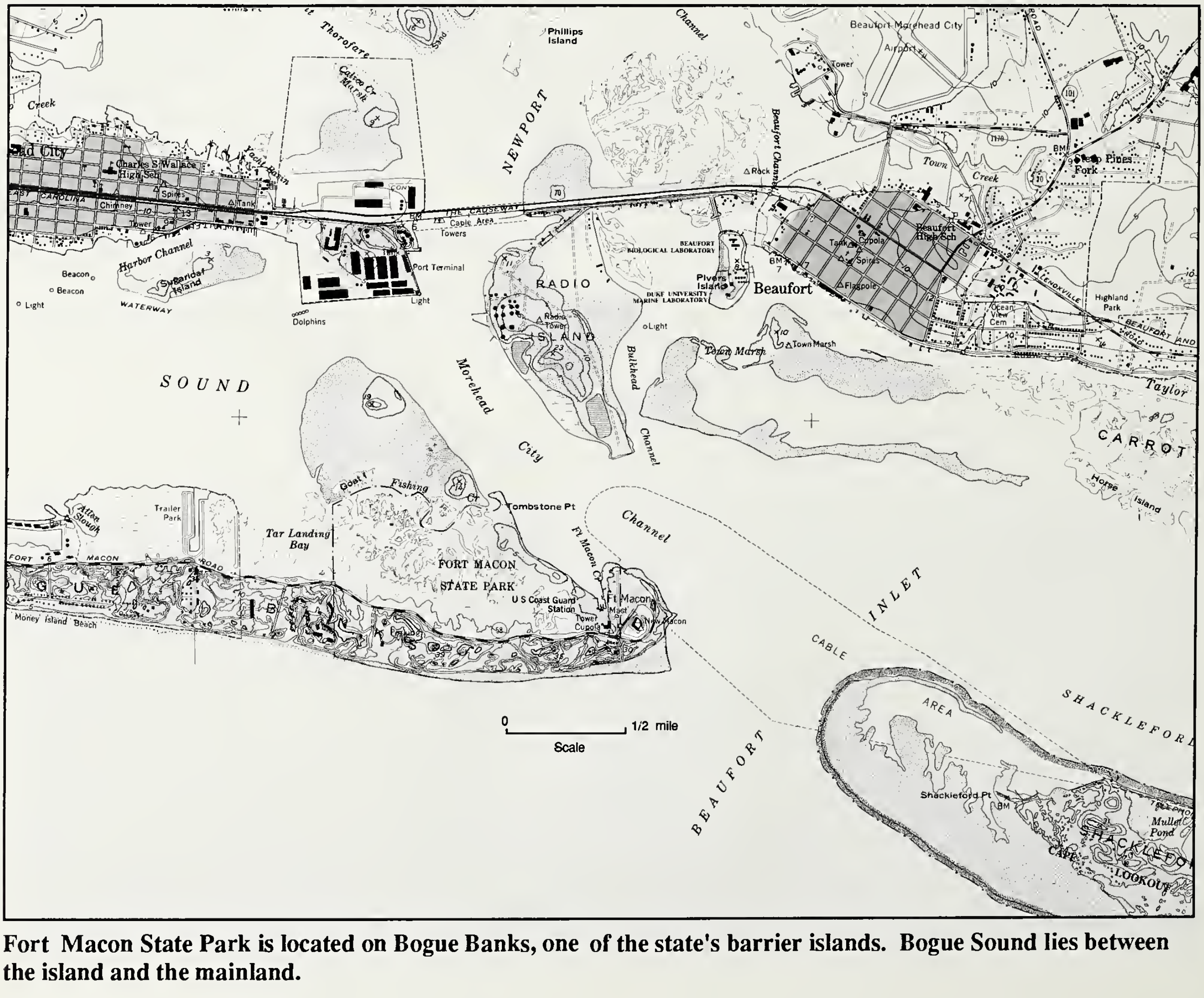
Three major barrier island environments occur in the park. These are the salt marsh, which is present on the sound side of the island; the maritime shrub thicket, a band of thick vegetation along the center of the island in the park; and the dune/beach environment which fronts the ocean and lies mostly on the seaward side of the park road.

The ***salt marsh*** is not easily accessible except by boat; however, it can be seen along the sound from the park road immediately after entering the park. Salt marshes develop in the relatively quiet waters of the sound on "new" land formed by washover and tidal delta deposits. Cordgrass and other salt tolerant plants able to withstand repeated tidal flooding are common in salt marshes.

The ***maritime shrub thicket*** lies seaward of the salt marsh on land above the high spring tide level. This environment consists of low-growing wax myrtle, black locust, red cedar, beach holly, cat briars, and prickly pear cactus. Scattered pockets of small live oaks indicate the beginnings of a maritime forest environment. A good example is along the ocean side of the park road just past the entrance to the bath house and picnic area. Roosevelt Natural Area, located about 12 miles west of the park, consists of mature maritime forest vegetation. The ***Elliott Coves Trail*** begins near Fort Macon and continues through the maritime shrub thicket before winding back to the parking lot along Beaufort Inlet.

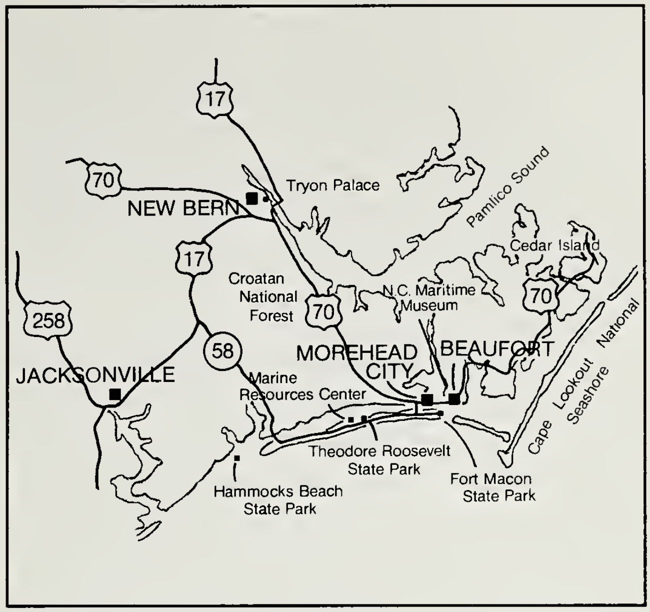
Dunes built by blowing sand face the ocean immediately behind the beach. Dunes represent the first line of defense against the sea. Areas where the dune system is low or narrow are most susceptible to erosion and overwash. Conversely, areas where the dune system is well developed and stabilized by vegetation, such as sea oats or beach grass, will best survive the force of the sea. Some dunes in the park are 40 feet high.

Evidence of active barrier migration is seen by the way the dunes are drifting into the maritime shrub thicket. In turn, as the salt marsh receives additional sediment from tidal floods or periodic overwash, it will be overtaken by shrub thicket vegetation. Similarly, the salt marsh will continue to expand into the sound and the dynamic process of barrier island migration will continue.



Fort Macon State Park is located on Bogue Banks, one of the state's barrier islands. Bogue Sound lies between the island and the mainland.

HAMMOCKS BEACH STATE PARK



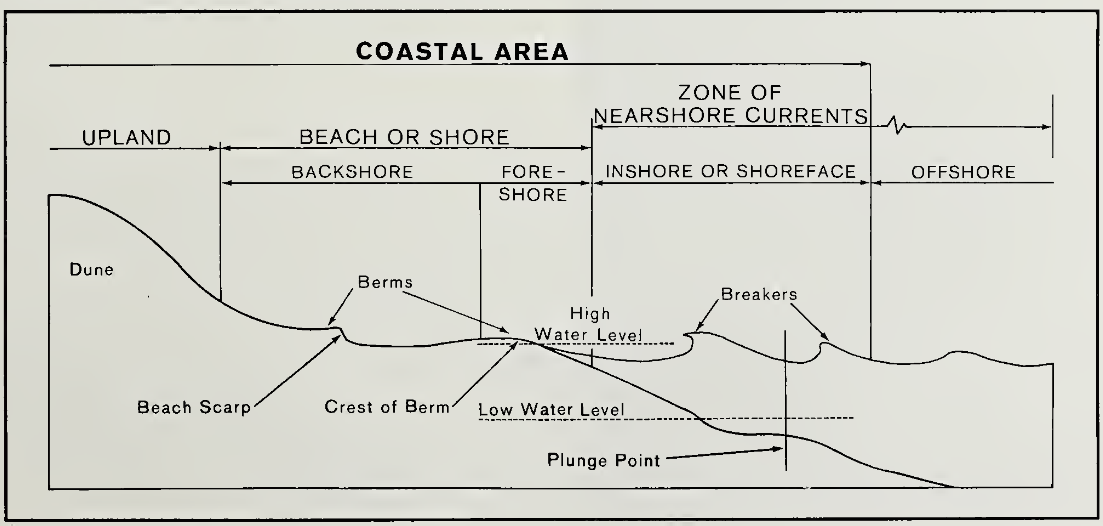
Hammocks Beach State Park is located on Bear Island 4.5 miles west of Swansboro. It is reached by a free passenger ferry during the summer months or by private boat year round. The ferry landing is at the end of secondary road 1511, south of Swansboro. The park has one of the most beautiful, unspoiled beaches on the Atlantic coast.

GEOLOGIC FEATURES

The major features of Hammocks Beach State Park are 1) extensive ***salt marsh*** and the lack of open sound on the land side of the island, 2) a large area of shifting dunes, 3) limited areas of thicket or forest, 4) a wave-cut ***scarp*** behind the beach, and 5) shifting ***inlets.***

Bear Island is slowly moving landward by the following process. Sand is brought to the beach from the nearby ocean floor by waves and currents. The prevailing winds carry the sand from the beach area up onto a new dune forming behind the beach. The wind then pushes the sand up the side of the dune until it reaches the top of the dune and slips or avalanches down the other side. Vegetation on the dune catches or deflects the shifting sand and influences the shape and landward progression of the dune. Finally, the active dune shifts across the island into the salt marsh at the landward side of the island. Trees and shrubs of the small forested areas are, in some places, covered by the dune. Inlets at both ends of the island also shift constantly. In the last 30 years, Bogue Inlet at the northeast end of the island has shifted more than Bear Inlet at the south end of the island.

One interesting feature along this part of North Carolina's coast is the age of the seashells found on the beach. Many of the shells are between 7,000 and 9,000 years old. Some of the shells are from animals that lived on the landward side of the island. These shells were uncovered after the island migrated landward. The sea rips up old ***lagoon*** deposits which are now exposed just off the beach. The shells are finally washed onto the beach.

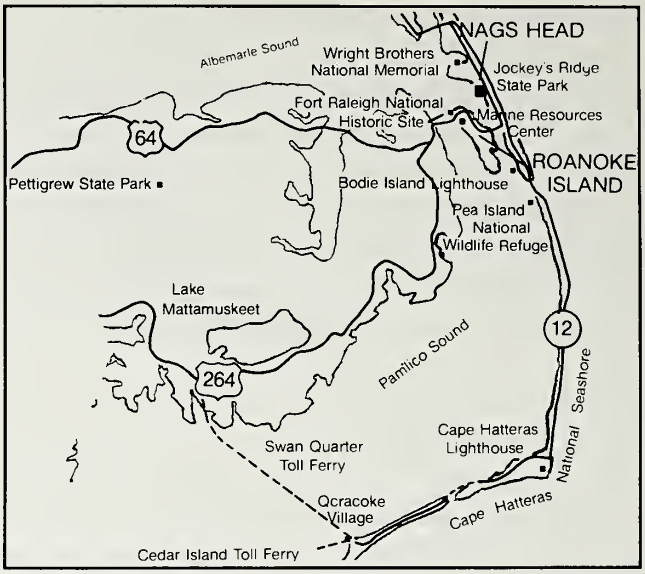


Beach terminology.

JOCKEY'S RIDGE STATE PARK

Jockey's Ridge State Park, located on the North Carolina Outer Banks at Nags Head, features the highest sand dune on the eastern United States coast. The dune towers up to 100 feet above the surrounding low-lying countryside and is visible from many miles away.

The park is located on Bodie Island, 10 miles northeast of Manteo, via U.S. highways 64 and 158. Jockey's Ridge is the largest and highest of a series of dunes that includes Run Hill, Engagement Hill, Pin Hill, and Seven Sisters. The first lands for the park were purchased in 1975 in response to an increasing public desire to protect the dune from encroaching development from Nags Head.



GENERAL GEOLOGY

Sand *dunes* are comprised of wind blown sand. Development of dunes relies heavily upon the establishment of vegetation or some other agent such as sand fencing which can slow down the wind and reduce the wind's capacity to move the sand. Wind with a velocity of about 12 miles per hour will transport dry, loose sand. On the Outer Banks, sea oats and other types of beach grass are the primary agents which aid dune development. Continued development of the dune depends on its ability to survive erosive forces such as ocean flooding or man's influence. Migration of the dunes will tend to diminish, or the dune will stabilize, as vegetation gains a foothold on the dune and roots hold the sand in place.

Jockey's Ridge.

Just as the factors controlling dune development and migration are irregular, sporadic, and interrelated, so is the history of any particular dune or dune complex. Our knowledge of the Jockey's Ridge dune is limited to historical accounts. The dune dates back at least to the time of early French and Spanish exploration of North America. In the early 1800's, the Nags Head area, with Jockey's Ridge as a prominent attraction, was a popular vacation resort.

Aerial photographs from 1949 to the present indicate no appreciable changes in the size or location of the dune complex except for a very gradual southwestward migration. Individual peaks and depressions within the dune area vary in size and location seasonally or over periods of several years, but the overall change is not significant. This is because the wind patterns for the area tend to "cancel" each other. Dune migration caused by southeast winds is counteracted by migration caused by northeasterly winds. The southeast winds are dominant from March through August. The northeast winds are dominant from September through February.

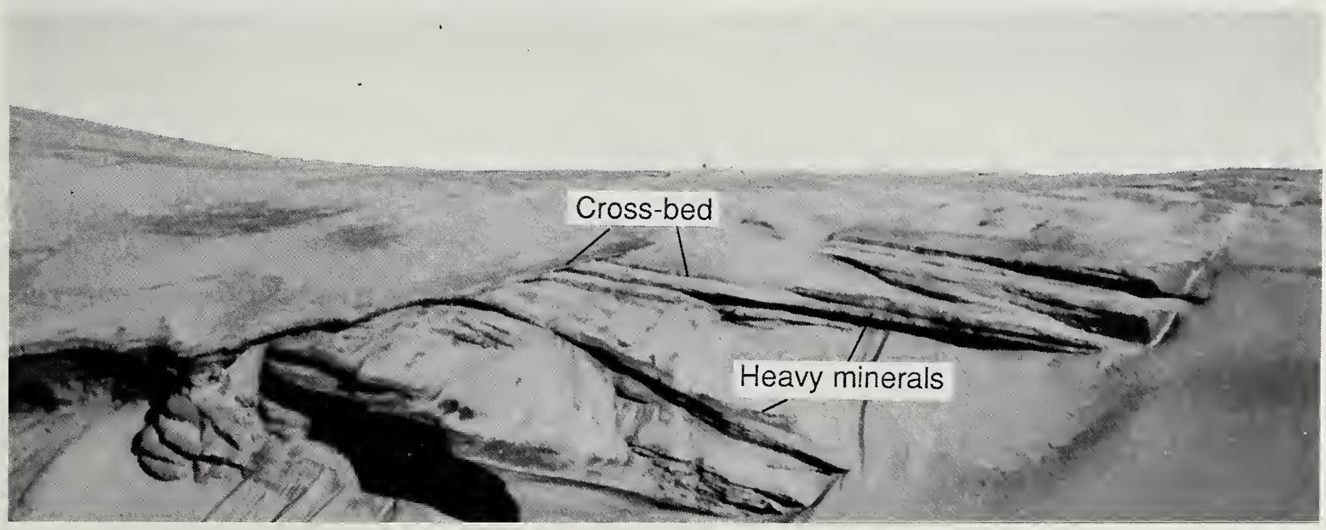
A number of features and processes may be observed within the park. First is the sand itself. It is mostly fine grained and well sorted (the majority of the grains are the same size). Finer grained material is blown away or winnowed because it is lighter and more easily transported by the wind. Coarser grained materials, such as gravel, are too heavy to be carried to the dune area from the beach except by flooding or by very strong winds. The abrasive action of the sand grains striking each other as they move along the dune's surface tends to break off any edges, thus giving the grains a rounded form. This process, nothing more than natural sand blasting, creates a frosted surface on the grains.

The sand is comprised chiefly of the mineral quartz. In lesser amounts, other minerals such as feldspar, mica, calcite (from broken shells), and a group of dark minerals, collectively referred to as heavy minerals, are found in the dune environment. The heavy minerals are most noticeable where they are concentrated in individual layers or laminations. This occurs because lighter-weight minerals are blown away by winds not strong enough to transport the heavy minerals.

The internal dune structure consists of thin layers, called cross-beds or cross-laminations, which lie at various angles to the overall dune form. They form on the leeward side (side away from the wind) and record the direction of the wind that deposited the layer. A set of cross-beds represents only a very short period of time, perhaps only days, of the dune's history. The angled accumulations of sand are generally exposed on portions of the windward side of the dune as covering sand is blown away.

In addition to the peaks and ridges of the dune system, there are also bowl-like depressions which are called ***blowouts***. Blowouts result from a process known as ***deflation***. This occurs when turbulent wind currents scour out the depression. The trail from the parking lot opens up into a blowout area. As deflation proceedes, vegetation root systems become exposed and the plants die, thus increasing the area's vulnerability to further deflation. Sometimes deflation advances to the point where the surface is scoured down to the water table and the result is a pond in the blow-out area.

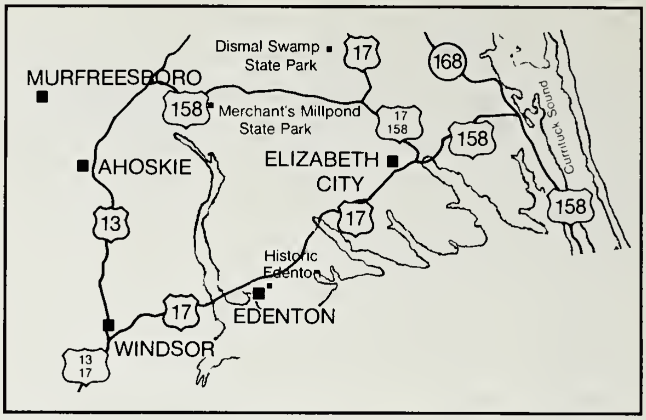
Dune areas, and especially Jockey's Ridge because of its height, are often the location of lightning strikes. On rare occasions, the energy of the lightning bolt fuses the sand to form fragile, irregularly shaped tubular or cone-shaped glass objects called ***fulgurites***. They generally are found on the higher elevations after surrounding loose sand is blown away to expose the fulgurite. Fulgarites that have been found in the park are up to several inches in length and about one-half inch in diameter. Sometimes they have a branching form.



Cross-bedding in the dunes at Jockey's Ridge. The dark layers are heavy mineral concentrations.

MERCHANTS MILLPOND STATE PARK

Merchants Millpond State Park is located in central Gates County, 6 miles northeast of Gatesville. The Millpond covers approximately 500 acres behind a dam built across Bennetts Creek, a tributary of the Chowan River. Corn and wheat milling operations at the site date back to 1812.



GENERAL GEOLOGY

The park area is underlain by sand and clay of ***Quaternary age*** (up to about 2 million years old). Quaternary deposits similar to these blanket the surface of most of the state's Coastal Plain. Information from a water well drilled in the park indicates that this uppermost geologic unit is about 50 feet thick. Below the surface unit, shell marls, sand, sandstone, clay, and some limestone extend to a depth of about 1,500 feet.

The Atlantic Coastal Plain is underlain by a sequence of sedimentary rocks whose thickness ranges from a few feet, where it laps onto the crystalline rocks of the Piedmont region, to nearly 10,000 feet at Cape Hatteras, and even thicker offshore. These sedimentary rocks have accumulated for over 100 million years along the gradually sinking or subsiding margin of the North American continent.

Although the overall effect has been a subsiding continental margin, the different types of sediments found in wells drilled in the Coastal Plain indicate that the process that formed the sediments was complex. For example sedimentary rocks that were deposited in a shallow ocean setting occur as far inland as Raleigh. Also, in the

Merchants Millpond.

present day offshore area, deposits that were laid down along the banks of rivers and streams of an emerged Coastal Plain are now found in the subsurface. These findings demonstrate that the ocean has migrated back and forth across the continental margin in a series of ***transgressions*** and ***regressions.***

The sea left behind a series of flattened surfaces or terraces that decrease in elevation from the Piedmont to the present shoreline. Some terraces are separated by somewhat steeper slopes called ***escarpments*** which represent former barrier islands. In some areas features such as preserved ancient dunes or inlets are associated with the escarpments.

As many as seven terraces are interpreted along the Atlantic Coastal Plain. Localized movements of the earth and erosion of the terraces, escarpments, and associated features, however, have made recognition of the upper terraces difficult and subject to more than one interpretation. In the lower elevations of the Coastal Plain, the features are more clearly delineated. For example, a fairly continuous escarpment known as the ***Suffolk Scarp*** can be traced on topographic maps, aerial photographs, and satellite photographs through Beaufort, Washington, and eastern Gates counties. This 10-15 foot high escarpment separates the lowest Coastal Plain terrace, which lies east of the scarp, from a second terrace. Merchants Millpond State Park lies in the second trerrace.

In the park area the terrace elevation is almost 40 feet above sea level. Bennetts Creek and its tributary streams have eroded down into, or ***dissected***, this terrace to form flat, swampy flood plains which lie at elevations of less than 10 feet. The average elevation of the Millpond is 6.5 feet.

Slopes formed between the terrace and the bottom lands are relatively steep compared to other areas of the Coastal Plain. This combination of steep slopes and deeply cut drainages is especially favorable for the creation of artificial lakes and ponds by building dams where the valleys narrow. This may account for the apparent abundance of millponds in the northern Coastal Plain as compared to the central and southern parts.

The park's interpretive center houses an exhibit of Indian ***artifacts*** found within the park. Since there are no natural outcrops of hard rock in the immediate vicinity of the park, these crude tools must be made from rocks that were found elsewhere. One rock type can be identified as coming from the Kinston area. This is a hard, dark gray mudstone unique to that area. The white or cream colored sandstone originated in the Piedmont or possibly the mountains of Virginia. Rocks similar to these are found in the surficial deposits of southeastern Virginia. They may have been carried this far into the Coastal Plain by floods. Some of the larger boulders may even have been transported in ***ice blocks*** which formed in the upper reaches of the ancestral James River. The blocks of ice floated downstream and eventually dropped the boulders as the ice melted. The gnarled stumps of trees swept downstream in floods also can transport large boulders. The discovery of these rare but essential hard items was likely an important event to the former inhabitants of the lower Coastal Plain.

CAROLINA BAYS

Shallow, oval depressions called Carolina Bays occur in the Atlantic Coastal Plain from Florida to New Jersey. The extent of the bays was not truly known until aerial photographs became available, revealing the large number and nature of these striking geomorphic features. It is estimated that there are as many as 500,000 bays, the majority of which are in North and South Carolina, hence the name ***Carolina Bays***. The greatest concentration of bays is in the swampy area northeast of the Cape Fear River in Bladen County.

Rather than describing a body of water, the term ***bay***, in this case, refers to the distinctive vegetation, such as loblolly bay, that fills these depressions. All the depressions were once lakes; however, the vast majority were filled naturally with sediment and vegetation or were drained for agriculture. Only a few bays still contain water. By studying pollen grains, geologists have determined that these bays were formed 40,000 years ago during the ***Pleistocene Wisconsin Ice Age***. No Carolina Bays are being formed today.

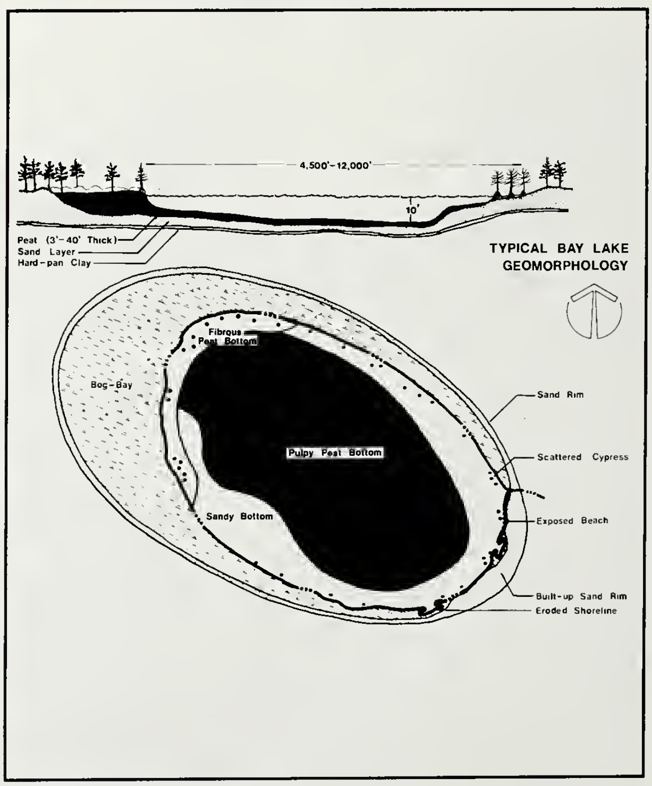
Many theories have been proposed to explain the formation of Carolina Bays. These theories generate much debate among scientists but no agreement has been reached. These theories are explained below.

GEOMORPHOLOGY

Carolina Bays are shallow, elliptical depressions oriented in a southeast-northwest direction. Bays are only found in the loose, unconsolidated sands that form a cover within the Coastal Plain. The greatest concentration of Carolina Bays is in Bladen and Columbus Counties where, in some areas, they cover up to 50 percent of the land surface. A ***sand rim*** is present around most bays and is usually best developed along the southeast end of the bay. The sand rim is thought to be formed by wind action on the bay.

While a small number of Carolina Bays still contain water, most are completely overgrown. The bays have dense vegetation with a distinctive plant community including loblolly

Aerial photograph showing the concentration of Carolina Bays in the Coastal Plain.



Bay lake geomorphology.

bay, red bay, and sweet bay. The barren sand rim, in contrast, is nutrient-poor and dry with little or no soil development or water-holding capacity. It supports only sparse stands of turkey oak, long leaf pines, mosses, and wire grass. Carolina Bays can be distinguished from surrounding areas on the basis of vegetation alone. Bays that still contain water were at one time much larger water bodies but are gradually shrinking in size as the vegetation continues to take over.

Peat deposits formed in Carolina Bays as part of the natural lake filling or "overgrowth" process. Peat consists of partially decomposed plant material that is formed as plants die and are buried in the swampy, organic-rich environment of the Carolina Bays. The tea-colored water in most water-filled bays is formed by the leaching of humic acid from the peat deposits. Today, peat deposits are considered a potential source of energy. Extensive peat deposits in the Coastal Plain of North Carolina formed in ***pocosins*** along the coast and in Carolina Bays. These peat deposits are described in Bulletin 88, ***Peat Deposits of North Carolina***, available from the North Carolina Geological Survey Section.

THEORIES OF ORIGIN

Many theories have been proposed to explain the origin of the Carolina Bays. These include: 1) meteorite impact; 2) solution by artesian springs and streamlining of bays by wind and current action; 3) solution of limestone and streamlining of bays by the flow of groundwater; 4) the activity of fish swimming around submarine springs; and 5) oriented lakes. While there is no general agreement on the origin of the Carolina Bays, the oriented lakes theory is best supported by scientific evidence.

The ***meteorite impact*** theory suggests that the Carolina Bays were formed by a swarm of meteorites that crashed into the earth at a low angle from the northwest. It is suggested that air shock waves, generated by meteorite impacts, created the shallow, elliptical depressions in the loose, unconsolidated sands that blanket the Coastal Plain. According to this theory, the shape of the bays was also influenced by the earth's rotation at the time of impact. This theory is still very popular but is not well supported scientifically. No meteorite material has been found in the bays, and a subbottom profile of Singletary Lake shows no evidence of disturbance such as a meteorite impact would make.

Theories of bay development by artesian springs or the solution of limestone by groundwater have been discounted because many Carolina Bays are found outside of areas where artesian springs develop or limestone occurs.

The ***oriented lake theory*** is the most widely accepted theory of bay formation. Oriented lakes are elliptical lakes that have a consistent orientation along the long axis of the lake. The theory states that Carolina Bays were ponds of water streamlined by the erosive action of wind-generated lake waves. Over time, the prevailing winds cause the water to erode rapidly along the ends of the lakes perpendicular to the direction of the prevailing winds. This process results in an elliptical lake oriented perpendicular to the direction of the prevailing winds.

In the area of the Carolinas, according to this theory, prevailing winds from the north-northeast created the southeast-northwest orientation of the Carolina Bays. After the lakes stabilized, sand dunes developed in response to strong intermittent northwest winds. This is evidenced by the well developed sand rims on the southeast end of the bays. As the climate changed and warming began after the Wisconsin Ice Age, precipitation decreased and the bays filled with water more slowly. The bays began to be overtaken by vegetation. This "overgrowth" process continues today.

LAKE WACCAMAW STATE PARK

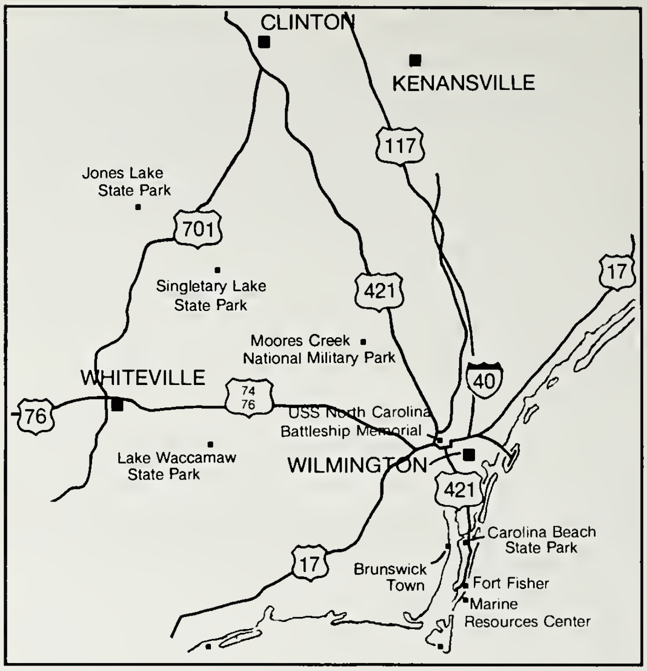
Lake Waccamaw State Park is located at the end of State Road 1947, 6 miles southeast of the town of Lake Waccamaw in Columbus County.

Lake Waccamaw is the largest Carolina Bay that still contains water and is the second largest of all Carolina Bays. It is approximately 6 miles long and lies at an elevation of 43 feet above sea level. Maximum water depth is 11 feet. A sand rim, located along the southeastern edge of the lake, is 23 feet high and 2,000 feet wide. Lake Waccamaw State Park is within this sand rim.

Lake Waccamaw forms the headwaters of the Waccamaw River which flows from the southwestern edge of the lake. Big Creek flows into Lake Waccamaw along the northeastern edge of the lake. Exposures of the ***Upper Cretaceous Peedee Formation***, the ***Pliocene Duplin Formation***, and the ***Pliocene-Pleistocene Waccamaw Formation*** are in a 15 foot bluff that is on the northeastern shore of Lake Waccamaw. The water in most Carolina Bays is naturally very acidic, but the water in Lake Waccamaw is neutral because of the solution of limestone which underlies the lake. An outcrop of this limestone occurs along the northeastern edge of the lake.

Lake Waccamaw is a unique Carolina Bay in that it has a sandy bottom along the entire shore. Peat deposits lie in a northwest-southeast-trending band in the middle of the lake.

Aerial photograph showing Singletary Lake.



SINGLETARY LAKE STATE PARK

Singletary Lake State Park is located on the east side of North Carolina Highway 53, 12 miles southeast of Elizabethtown in Bladen County. The lake is 70 feet above sea level and lies in a low, poorly drained, swampy area northeast of the Cape Fear River.

The Upper Cretaceous ***Black Creek Formation*** underlies this area and is covered by a veneer of surficial deposits of Pleistocene age. The Black Creek Formation consists of a mica-rich gray to black sandy clay and sand. Fine lignite and sulfur are commonly found throughout the formation. A classic outcrop of the Black Creek Formation is at Walkers Bluff on the Cape Fear River near Singletary Lake.

The road to the bunkhouses and pier is located in the sand rim along the southeast side of Singletary Lake. The sand rim supports very little vegetation; it has a stark, almost desert-like appearance that is very striking.

North Carolina Highway 53 follows the southwest edge of Singletary Lake. On the east side of the road is the dense bay bog vegetation characteristic of Carolina Bays. The west side of the road is the sparsely vegetated sand rim. Stabilized sand dunes can be seen along the dirt road that runs along the east side of Singletary Lake. Again, in this area you can view the striking contrast between the sand rim and the vegetation-filled areas of the bay. (The rare Venus Fly Trap plant grows along the border between the sand rim and bay bog.)

JONES LAKE STATE PARK

Jones Lake State Park is located on the west side of North Carolina Highway 242, 4.5 miles north of Elizabethtown in Bladen County.

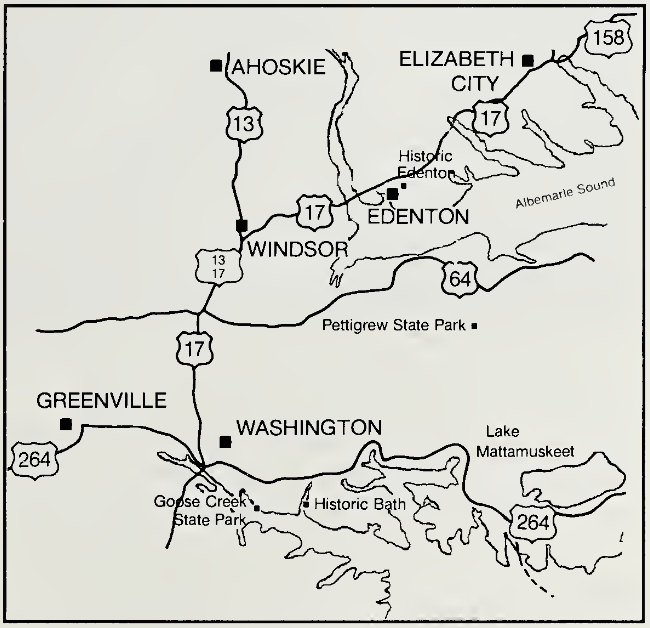
Jones Lake, like Singletary Lake, is a classic example of a water-filled Carolina Bay. It is 60 feet above sea level. The general recreation area and campsites are located in the sand rim along the southeastern part of the bay. A nature trail around the perimeter of the lake provides the unique opportunity to walk through the densely vegetated bay bog area of a Carolina Bay.

PETTIGREW STATE PARK

Pettigrew State Park is 9 miles south of Creswell on the northern shore of Lake Phelps. Lake Phelps is a 16,600 acre water body that lies on the Pamlimarle Peninsula between the Albemarle Sound and Pamlico River. A sand rim is absent around Lake Phelps, a factor in the argument against considering this lake as a Carolina Bay. On the other hand, the shape and orientation of the lake are factors that support the idea that the lake is a bay. It may be, in fact, a ***double bay***.

This area consists of vast, low-lying swampy land which includes bays, marshes, and fresh-water wetlands known as ***pocosins***. The area has gradually yielded to development since its settlement in the late 1700's. Exploitation of the rich timber resources was followed by ditching and the building of canals for better drainage and for transportation. This, in turn, promoted agriculture, the primary resource of the area for over a century.

In the early 1970's, oil embargos and soaring fossil fuel prices generated commercial interest in the area's huge peat resources. The extensive peat deposits of the Pamlimarle Peninsula developed over the past 10,000 years as the decaying leaves, roots, and stumps of lush vegetation accumulated in stream channels, shallow lakes, and fresh-water marshes. These deposits are locally greater than 10 feet thick but average about 4 feet thick. Within the Pamlimarle Peninsula, peat deposits cover a total area of over 350,000 acres. Bulletin 88, ***Peat Deposits of North Carolina***, locates and describes the peat deposits. This publication is available from the N.C. Geological Survey.



WEYMOUTH WOODS SANDHILLS NATURE PRESERVE

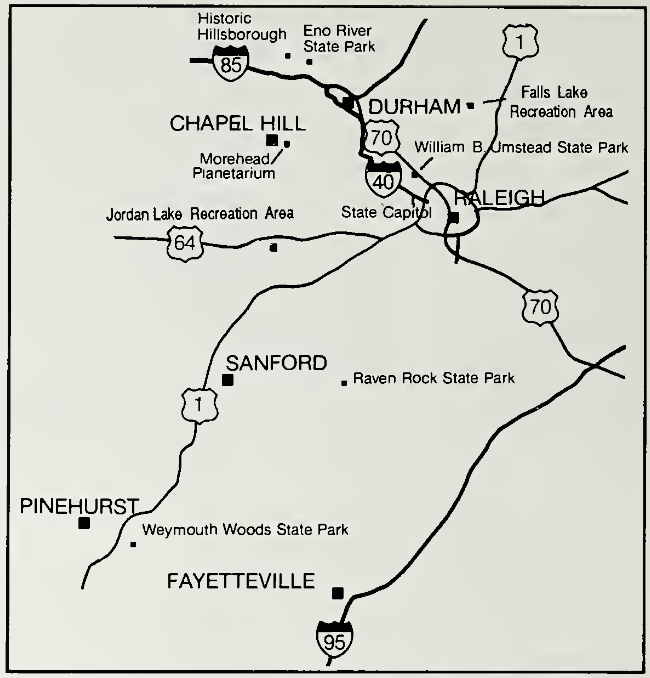
Weymouth Woods Sandhills Nature Preserve is in Moore County, approximately 1 mile southeast of Southern Pines off highway U.S. 1. This 628 acre preserve is bounded by Ft. Bragg-Aberdeen road (SR 2074) to the south and Connecticut Avenue to the north. The preserve is in the southwestern portion of the Coastal Plain Physiographic Province in an area known as the ***Sandhills region.***

Mill Creek, an east-west trending tributary of James Creek, divides the preserve almost equally into north and south areas. The creek contains a swampy floodplain (Jones Creek swamp) that in places is more than 250 feet wide. A striking feature of this drainage is its elevation in relation to the local topography immediately to the north and south. To the south, at the preserve entrance, sand-capped hills form topographic highs 500 feet above mean sea level. To the north, 130 feet below the base of these hills, lies the incised channel of Mill Creek. This 130 foot difference in elevation occurs in a horizontal distance of less than 2,500 feet. The hills to the north of the creek are 460 feet above mean sea level at their highest point. This hilly Sandhills topography reflects a geologic history of uplift followed by dissection.

GEOLOGY

Sedimentary rocks in Weymouth Woods Sandhills Nature Preserve formed through a complex sequence of events millions of years ago. This sedimentary sequence gives us insight into the local and regional geologic history of the Preserve and its relationship to the one million acre area known as the Sandhills region.

Most of the sands capping ridges in the Sandhills region belong to the Pinehurst Formation of Tertiary age. Geologists do not agree on the origin of these sands. Many geologists once



thought that the sands were eolian, or wind blown, in origin. Recent studies suggest that they formed in a shallow, relatively quiet water embayment. Similar sands of marine origin in nearby Harnett County are described as Eocene in age. Eocene age rocks also occur south of Weymouth Woods. Regardless of the formation of the Pinehurst Formation, the surface sands have been reworked by winds during recent times.

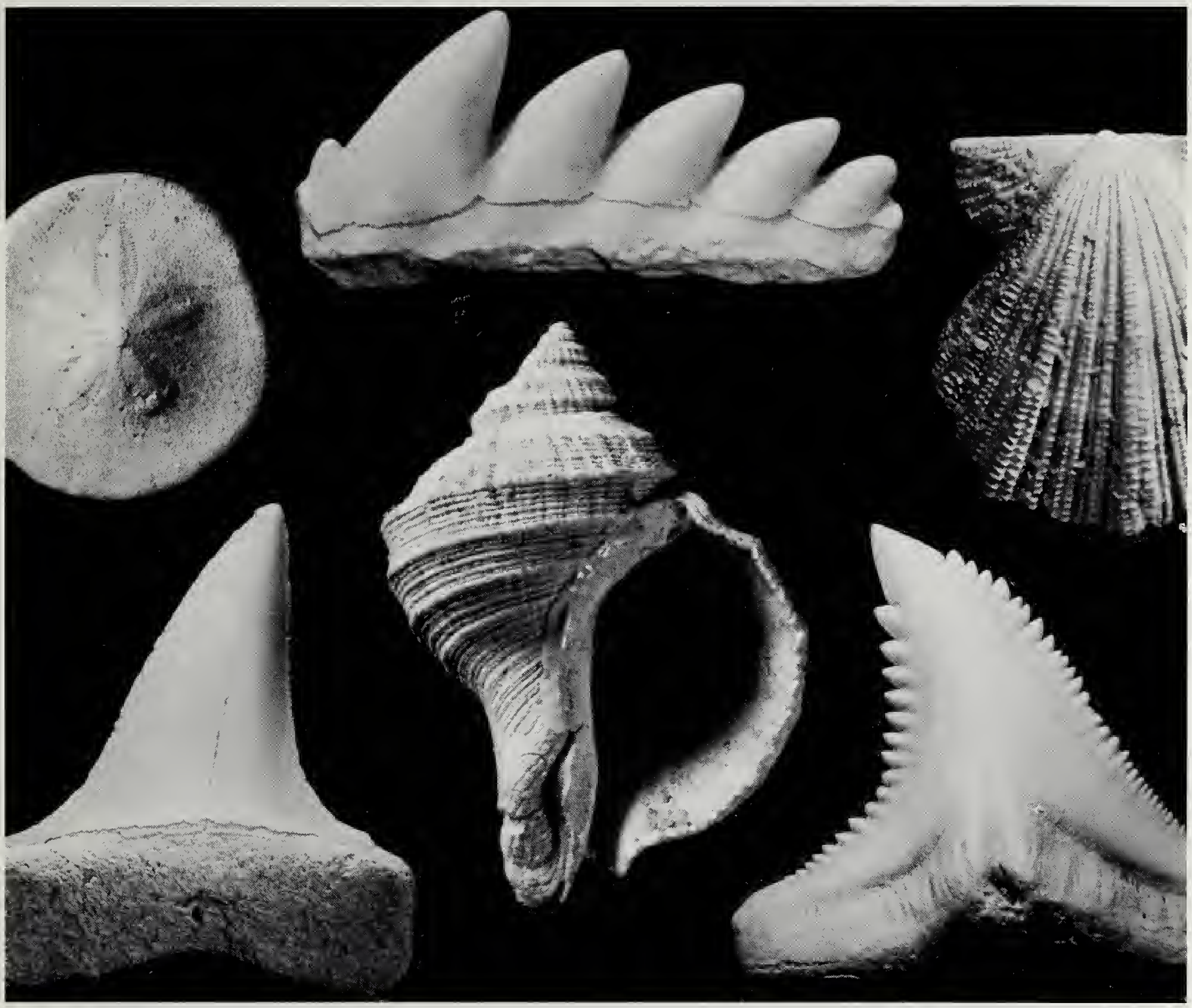
The high-level layers of loose, light-colored sands of the Pinehurst Formation that cap the hills are significant because they contain large amounts of white quartz with only a few other minerals. The distinctive rolling, hilly terrain and high topographic position of these sands are the primary reasons the Sandhills are so named. Elsewhere,. the Sandhills are a source of quartz for the manufacture of high-quality glass products.

Underlying the sands of the Pinehurst Formation are poorly indurated sandstones and sandy clays of the Middendorf Formation. The Middendorf Formation in turn overlies slightly more indurated sandy clays and clayey sands of the Cape Fear Formation.

The ***sedimentary rocks*** of the Middendorf Formation are best exposed in the northern half of

Weymouth Woods away from the drainage basin of Mill Creek. They are interlayered reddish-brown to orange-brown sandstone and sandy clay. The sandstone is ***cross-bedded*** with beds lying at angles to each other. Occasional gravel beds, iron-cemented sandstone, and petrified wood are found within this area of the preserve.

The Cape Fear Formation has not been recognized at the surface in the vicinity of the preserve but has been encountered in wells around Southern Pines.



Selected Coastal Plain fossils.

Top left. *Periarchus lyelli* (Conrad), 1834a, UNC 7611, Eocene Castle Hayne Formation at the Martin Marietta Ideal Quarry, northeast of Castle Hayne, New Hanover County, N.C. 32 mm in height.

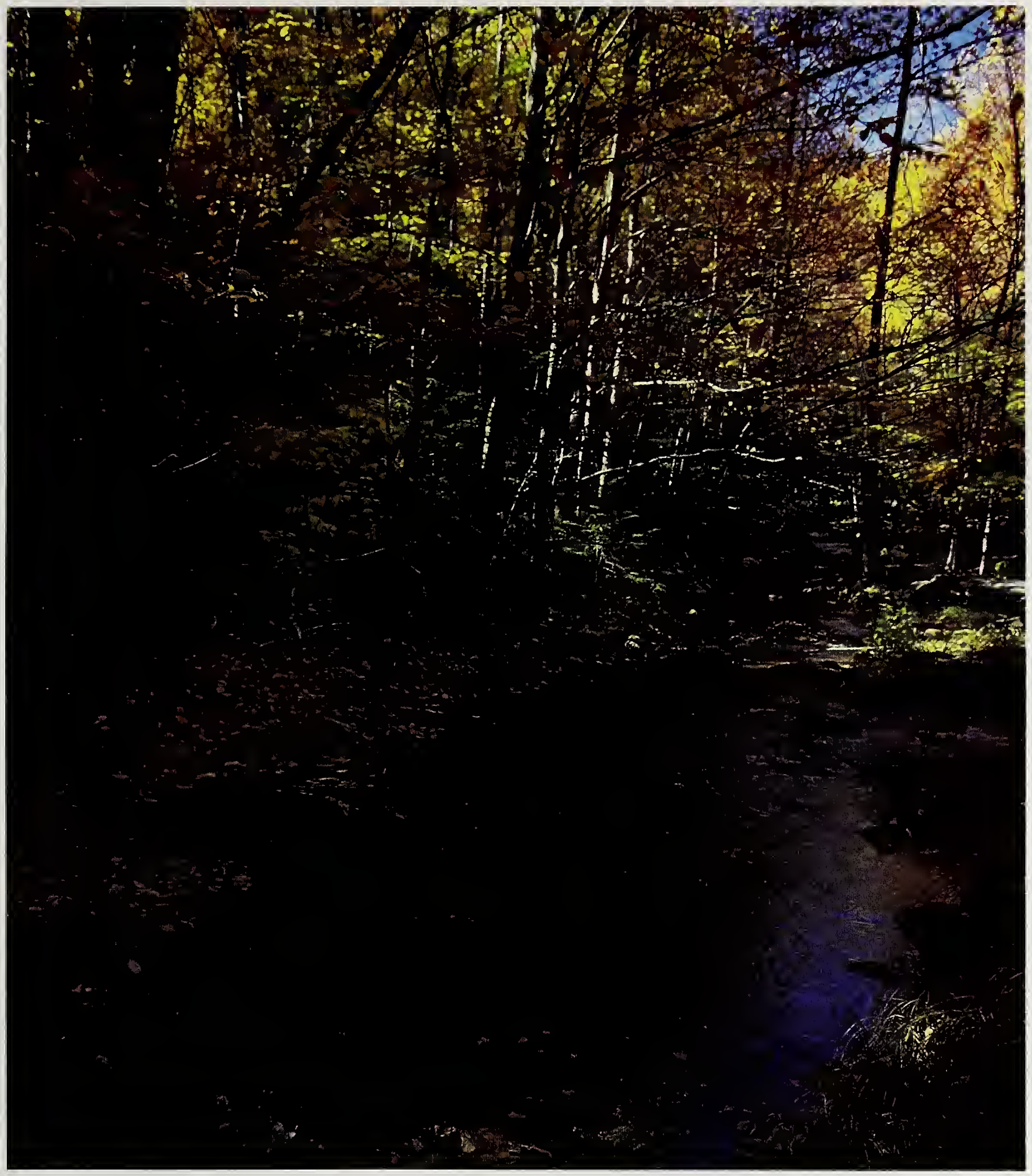
Top center. *Notorhynchus* aff. *N. serratissimus* (Agassiz), 1844, UNC 8467, Cooper Marl, upper bed, Giant Portland Quarry, Harleyville, South Carolina. 19.8 mm in length. Similar fossils occur in the River Bend Formation of North Carolina.

Top right. *Pecten trentensis* Harris, 1919b, UNC 12536d, Oligocene River Bend Formation, N.C. Department of Transportation Quarry, northeast of Pollocksville, Jones County, N.C. 21.2 mm in height.

Bottom left. *Oxyrhina praecursor* (Leriche), 1905, UNC 8429, Upper Eocene Cross Member of the Santee Limestone, Giant Portland Quarry, Harleyville, South Carolina. 25.1 mm in height. This species also occurs in the Eocene Castle Hayne Formation of North Carolina.

Bottom center. *Rapana gilletti* Richards, 1943, UNC 12526a, Late Oligocene or Early Miocene, Haywood Landing Member of the Belgrade Formation, Haywood Landing. 35 mm in height.

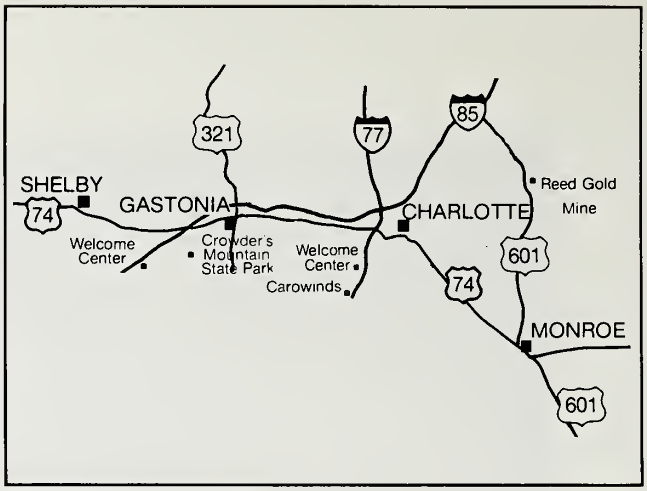
Bottom right. *Hemipristis serra* Agassiz, 1843, UNC 14231, North Carolina, probably from the Miocene Pungo River Formation. 25.5 mm in height.



Piedmont Parks

CROWDERS MOUNTAIN STATE PARK

Crowders Mountain State Park is in the western Piedmont in Gaston County, 6 miles west of Gastonia and 8 miles north of the South Carolina State line. Interstate 85 passes a few miles north of Crowders Mountain. The park was established in response to public concern that kyanite mining activities might destroy the beauty of the mountain.



GEOLOGY

The park is located in the ***Kings Mountain belt*** of rocks. These rocks are of both sedimentary and volcanic origin, and were deposited in a shallow basin or sea over 500 million years ago. They were later deeply buried, altered by heat and pressure (***metamorphism***) and then tilted on edge. Finally, they were exposed at the earth's surface through the processes of weathering and erosion. The most prominent feature of the state park is Crowders Mountain, a ***monadnock*** rising 750 feet above the surrounding Piedmont plateau.

The main rock types in the park are ***quartzite*** and ***phyllite*** of the ***Battleground Formation***. Quartzite is very resistant to weathering because of its high quartz content. It forms the park's major peaks such as Crowders Mountain and the Pinnacle. In places, the quartzite forms beds up to 600 feet thick. The quartzite contains crystals of an aluminum-rich mineral called ***kyanite***. A close look at the quartzite reveals crystals of kyanite in radiating clusters and in crystals aligned parallel to each other. (***It is illegal to collect samples.***)

The ***phyllite*** we see in the park contains the minerals ***mica*** and ***quartz***. In places it contains small amounts of kyanite, andalusite, pyrite, and, rarely, staurolite. The soil above this rock contains many small white mica flakes.

The Kings Mountain belt is rich in rock and mineral deposits that have been mined for feldspar, marble, lithium, tin, mica, kyanite, sillimanite, barite, gold, manganese, and iron. Quartzites such as those seen in the park were prospected nearby for kyanite and have been mined in South Carolina. Kyanite is used in making heat resistant ceramic products such as spark plug insulators.

West of the park, large deposits of ***feldspar***, ***spodumene*** (a lithium-bearing mineral), and ***mica*** are mined. North Carolina annually leads the nation in the production of these valuable mineral resources. A few miles west of the park was the most important gold mine in the district, the Kings Mountain Mine. This mine produced as much as $1 million in gold prior to 1895.

TRAILS

Crowders Trail begins at the park office and leads to the top of Crowders Mountain. The trail begins in ***quartz-mica phyllite***, which underlies lower elevations in the park. Phyllite is much less resistant to weathering than the quartzite. The phyllite is not well exposed, but tiny flakes of mica in the soil indicate that phyllite is near the surface. On the slopes of Crowders Mountain large quartzite boulders are scattered about. These boulders fall from the top of the mountain and moved down slope to where we see them now. Many of the boulders on the trail to the top of the mountain contain ***kyanite***. The kyanite is recognizable as white, blade-shaped crystals on the surface of the rocks. In some places the crystals weathered out of the rock and are scattered along the trail.

The boulders are cut by flat, straight surfaces called ***joints***. Joints are cracks in the rock that formed as the rock was deformed by forces deep within the earth or during removal of the overlying rock mass by erosion. It is usually possible to see numerous parallel joints and then other joints at different angles. Many of the rocks are also cut by very closely spaced parallel cracks that give the rock a layered appearance. This pattern is usually formed by the parallel alignment of platy minerals and is called ***cleavage***. It also formed when the rocks were deeply buried and is the result of forces that folded and faulted the rocks.

Near the top of Crowders Mountain, the steep cliffs are formed by quartzite. Along the trail below the cliffs is weathered quartz-mica phyllite. At the top of the mountain are spectacular views of the Piedmont. The skyline of Charlotte is to the east. Spencer Mountain, visible to the northeast, is another peak formed by the same type of quartzite as Crowders Mountain. To the southeast is Henry Knob, South Carolina, where kyanite was mined from the quartzites.

Cleavage is prominent in most of the rocks on top of the mountain. It is very steeply inclined and, in a few places, has small folds or contortions in the cleavage. ***Weathering pits*** are irregularly rounded depressions that developed on top of some of the boulders. The pits begin where some minerals weather more rapidly than others. Water collects in the resulting spaces in the rock surface, slowly enlarging the depressions, and merging them with others. This forms a distinctive ***pock-marked*** surface.

Rock Top Trail follows the ridgeline of Crowders Mountain. Most of the trail is across bare boulders and outcrops of kyanite quartzite. ***Weathering pits*** are well exposed in a large outcrop of quartzite near the top of a ridge. Where the trail crosses the road to the radio tower, weathered quartz-mica phyllite is exposed. Cleavage, the parallel alignment of mica flakes, is almost vertical in this rock. Just below the tower, a large quartzite boulder contains a quartz vein. The vein is only a few inches wide. It probably formed when the quartzite was deeply buried and hot silica-rich solutions filled cracks in the rock. The solution later cooled and solidified.

Pinnacle Trail follows a low ridge to the base of the Pinnacle and then up to the peak. ***Kyanite quartzite*** and many of the other features seen on Crowders Mountain are also seen in this area.

Cleavage in metamorphosed sandstone.

CLASSIFICATION OF METAMORPHIC ROCKS

	Texture	Composition	Rock Name
Foliated (contain parallel structure)	Coarse grained; grains parallel.	Feldspar, quartz, mica, hornblende, garnet.	Gneiss
Foliated (contain parallel structure)	Medium grained; grains parallel.	Mica, hornblende, talc, quartz, garnet, chlorite.	Schist
Foliated (contain parallel structure)	Fine grained; grains parallel.	Mica, quartz, chlorite, feldspar.	Phyllite
Foliated (contain parallel structure)	Very fine grained; dense, slaty cleavage	Microscopic flakes of mica, quartz, and feldspar	Slate
Non-foliated (Massive)	Granular; sometimes banded	Calcite or dolomite	Marble
Non-foliated (Massive)	Granular; massive	Quartz	Quartzite

DUKE POWER STATE PARK

Duke Power State Park occupies 1,452 acres in west-central North Carolina. It is approximately 10 miles south of Statesville in Iredell County. The park is on the north shore of Lake Norman, the state's largest man-made lake. The lake occupies 32,510 acres and 520 miles of shoreline when filled to capacity. It was formed by the Cowans Ford Dam, whose construction was begun in 1959 on the Catawba River. The lake powers Duke Power company's hydroelectric generators at the dam, and also is a source of cooling water for "steam-electric" generators at the coal-powered Marshall Steam Station. These two facilities, along with the recently completed McGuire Nuclear Station, provide power to a rapidly growing section of the Piedmont.

GEOLOGY

The park is located near the northern extension of a group of rocks called the ***Kings Mountain belt.*** This belt of rocks extends in a northeasterly direction from the South Carolina line for approximately 40 miles through Cleveland, Gaston, Lincoln, Catawba, and Iredell Counties. The Kings Mountain belt is bordered on the northwest by the Inner Piedmont geologic province and to the southeast it is bordered by the Charlotte belt.

The Kings Mountain belt consists of ***metamorphosed sedimentary*** and ***volcanic*** rocks such as quartzite, conglomerate, marble, quartz-sericite schist, hornblende gneiss, and biotite gneiss. The original sedimentary and volcanic rocks were deposited in a shallow basin over 500 million years ago. They were later deeply buried, altered by heat and pressure, and tilted on edge. Erosion has exposed the rocks at the land surface.

The rocks most often seen in Duke Power State Park are ***quartz-muscovite schist***, ***biotite gneiss***, ***granitic gneiss***, and ***amphibolite***. These rocks are poorly exposed because of deep weathering typical of most of the Piedmont. The best place to see the rocks is along the lake shore during low water levels. A few outcrops are scattered in the woods and along small creeks. Normally, the only indication of the type of rock beneath the surface is small, shiny flakes of mica or small scattered rock fragments in the soil.

One of the best exposed rocks is ***quartzite***, which occurs along a ridge 200 feet east of the main park entrance. The quartzite is exposed in a line, more or less continuously, for over 700 feet. The rock is composed primarily of white or colorless quartz with small amounts of mica and occasionally sillimanite. It forms ridges because it is more resistant to erosion than the surrounding rocks. The rock may have originally formed as a beach sand.

TRAILS

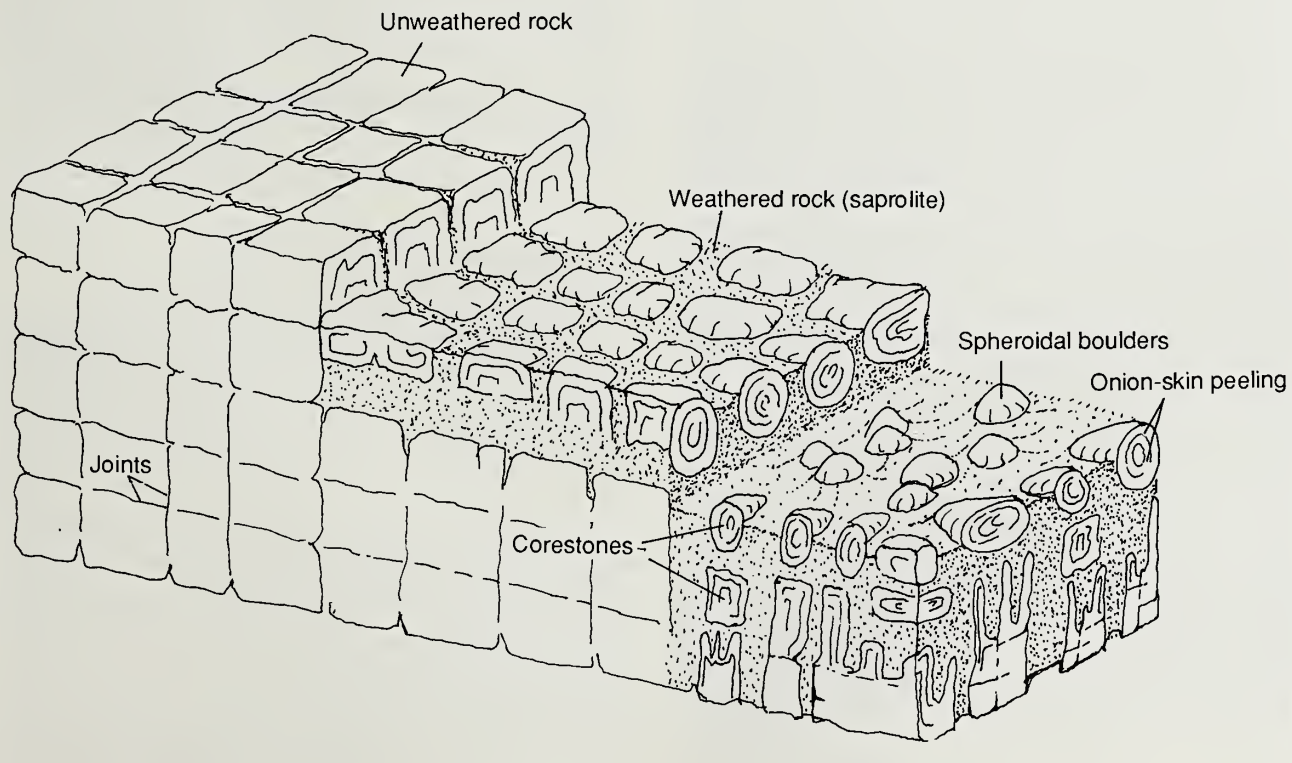
Swimming Area Trail - This trail follows the shoreline of a small peninsula which extends into Lake Norman. By following the right fork of the trail, the first rocks seen are boulders of ***biotite gneiss***. ***Biotite*** is a black variety of the mineral mica. The rock surface of the boulders has broken or peeled off along curved surfaces, a process called ***exfoliation***. Farther along, the trail passes the earthen dam which separates the small lake from Lake Norman. Granite boulders used as rip rap here were probably quarried nearby and trucked to this site for use in the dam.

Farther along the trail a boulder of ***amphibolite*** is exposed. Amphibolite is composed primarily of the iron-rich mineral ***hornblende***. The reddish stain on the exterior of the boulder is from hornblende weathering to iron oxide, much the same way rust forms on a nail. A good exposure of ***granite gneiss*** is on the east side of the peninsula after the trail turns back toward the swimming area. This outcrop is elongate parallel to layering in the rock. The layering is formed by alternating layers of dark- and light-colored minerals.

At the top of the hill near the picnic tables is an almost perfectly round boulder of massive ***granite***. This is an example of exfoliation which has resulted in the eventual rounding of a boulder. When a rounded boulder is formed, the process is called ***spheroidal weathering***. This is common in rocks that have well developed ***joints*** or ***fractures***.

Buildings in the swimming area are constructed from ***quartzite*** quarried just outside the park entrance. Quartzite, composed mostly of quartz, is a very hard, weather-resistant rock. A small quarry was opened in the rock to provide stone for construction in the park.

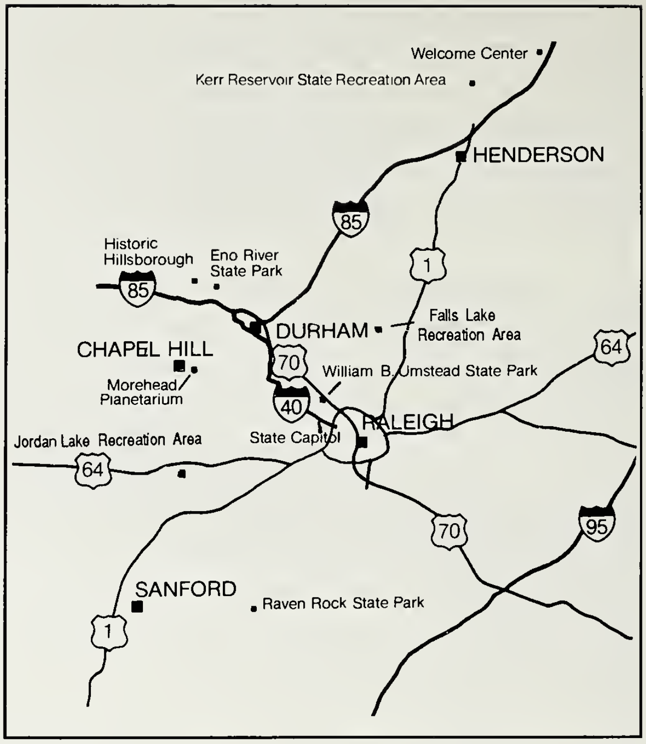
The ***loop trail*** from the camping area crosses ***biotite gneiss*** and ***quartz-sericite schist***. ***Schist*** is a rock composed principally of mica flakes aligned parallel to each other. This is easy to recognize, even when poorly exposed, because of the abundant mica flakes occurring in the soil. ***Biotite gneiss*** is exposed along the shoreline of the lake. The gneiss is broken into elongate fragments parallel to layering in the rock.



Spheroidal weathering develops in massive rocks, such as granite, that have regularly spaced joints. Joints act as avenues along which water moves. Water slowly dissolves minerals on the rock surface until the rock develops a rounded surface. The rock may peel off in layers or shells, much like an onion skin.

ENO RIVER STATE PARK

Eno River State Park is in the northern Piedmont of North Carolina, approximately 3 miles northwest of Durham. The park occupies 1,965 acres along the Eno River in northern Durham and Orange Counties.



GEOLOGY

The park is in an area known as the ***Carolina slate belt.*** This belt of rocks begins at the North Carolina-South Carolina State line at Union and Anson counties and trends northeasterly through the state to the North Carolina-Virginia State line. This belt is composed of interlayered ***volcanic lava flows***, ***pyroclastic rocks*** (pyro = fire, clastic = fragment), and ***sedimentary rocks.*** After deposition, cooling, and solidification, the volcanic rocks were deeply buried, folded, and faulted. At the same time they were changed by heat and pressure. This process is called ***metamorphism.***

The metavolcanic rocks in Eno River State Park were intruded by younger molten material called ***magma.*** The silica-rich magma crystallized at depth to form ***igneous*** (from the latin "ignis" meaning fire) rock called granite. These granitic intrusive rocks are now exposed at the earth's surface. Rain, snow, ice, and wind sculptured and eroded the park terrain and have exposed the outcrops of granite we see today.

Since there is no evidence of ancient volcanic vents, the metamorphosed volcanic rocks within Eno River State Park may have erupted from faulted areas known as ***fissures*** that were active periodically for millions of years. The volcanic rocks were deposited over two geologic time periods called ***Late Proterozoic*** and ***Cambrian.*** Volcanic deposition began in late Proterozoic time, from 700 to 570 million years ago, and continued through the Cambrian period, which began 570 million years ago and lasted for 70 million years.

Eno River is unique to this part of the Piedmont because of the numerous rapids in the areas underlain by metavolcanic rocks. These rocks are more resistant to erosion than the metamorphosed sedimentary and igneous rocks, and they form scenic white-water rapids. Rapids provide exciting canoe trips along this meandering, cascading river.

TRAILS AND ACCESS AREAS

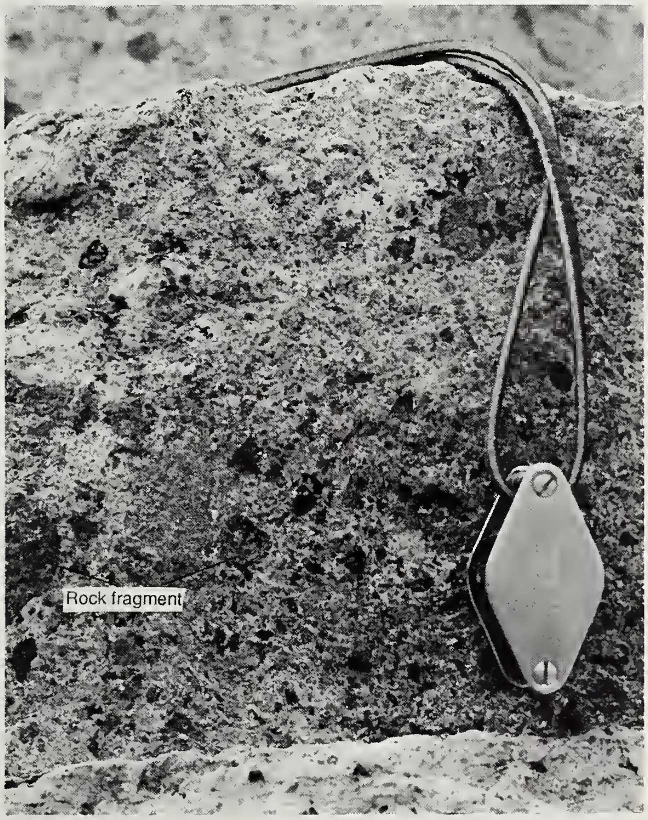
Cates Ford Access Area - The predominant rock types that can be seen in this area are ***metavolcanic flow rocks***, ***pyroclastic rocks***, and ***granitic rocks.***

The rock types at Cates Falls are pyroclastic rocks called ***tuff breccia*** (breccia is a rock that contains angular rock fragments). Interlayered with the pyroclastic rock is a volcanic mudflow that geologists call a ***lahar***. A lahar is a volcanic mudflow that contains unsorted, randomly oriented volcanic clasts or debris, ranging in size from less than an inch to blocks over 3 feet in length. These rock fragments also vary in composition and color, so that in outcrop, the lahar has a mottled gray appearance. Imagine volcanic debris lying on the flanks of a fissure or vent becoming saturated with as much as 60 percent water that condensed from steam from the fissure. This water-saturated volcanic debris begins to move downslope away from the fissure, following valleys or stream channels. The lahar can be viewed in outcrop where it is crossed by the Eno River at Cates Falls. The lahar forms the falls. Blocks over two feet in length can be seen in this easily-reached outcrop. Mudflows similar to this formed on the slopes of Mount St. Helens during the 1980 eruptions.

Cole Mill Access Area - A ***metavolcanic rhyolite lava flow*** is on the northwest side of Eno River along ***Bobbitt Hole Trail.*** The flow is a dense, light gray silica-rich rock that has a knobby texture on weathered surfaces. These knobs are formed by marble-size spheres called ***spherulites.*** They are composed of crystal clusters of the minerals quartz and feldspar that radiate outward from a center or nucleus. These spherulites range in size from less than one-tenth of an inch to over two inches in diameter. They formed as the glassy lava flows cooled and solidified. Because of the radiating form and shape of the spherulites, some early geologists identified them as silica-rich coral fossils of marine origin. But in 1899, a geologist named Joseph Diller correctly identified them as spherulites.

Cabes Land Loop Trail, 1.5 miles in length, provides the park visitor a hilly terrain for viewing the few geologic features exposed along the trail. Your hike begins in a red clay soil that developed from the underlying igneous intrusive granite. As the trail continues in a northerly direction toward the Eno River, a close look reveals that the granite weathered to produce ***saprolite.*** Saprolite is a term used to define a soft, earthy decomposed rock formed in place by chemical weathering. Large granite outcrops are absent along the hiking trail, but residual granite boulders are in the wooded areas near the river.

A contact between granite and metavolcanic rock occurs along the Eno River. This metavolcanic rock is a pyroclastic or fragmental volcanic rock called tuff. The tuff formed from debris that was blown from a fissure, settled to the ground, and solidified. The quartz and feldspar crystals visible in the tuff formed, or crystallized, as the pyroclastic rock cooled and solidified. At this outcrop, the rock trends in a northeasterly direction, and forms white-water rapids where it crosses Eno River. This was the old dam site for Cabe's Mill. The wooded island visible just upstream was formed as the dam stopped the flow of the river and impounded the water for Cabe's Mill. Sediment carried in suspension settled out into the river channel. Over the years, this bedded sedimentary deposit extended from the base of the dam to several hundreds of feet upstream. When the dam was destroyed, the river began to flow and entrench itself on each side of the sediment mass, forming the island that exists today.



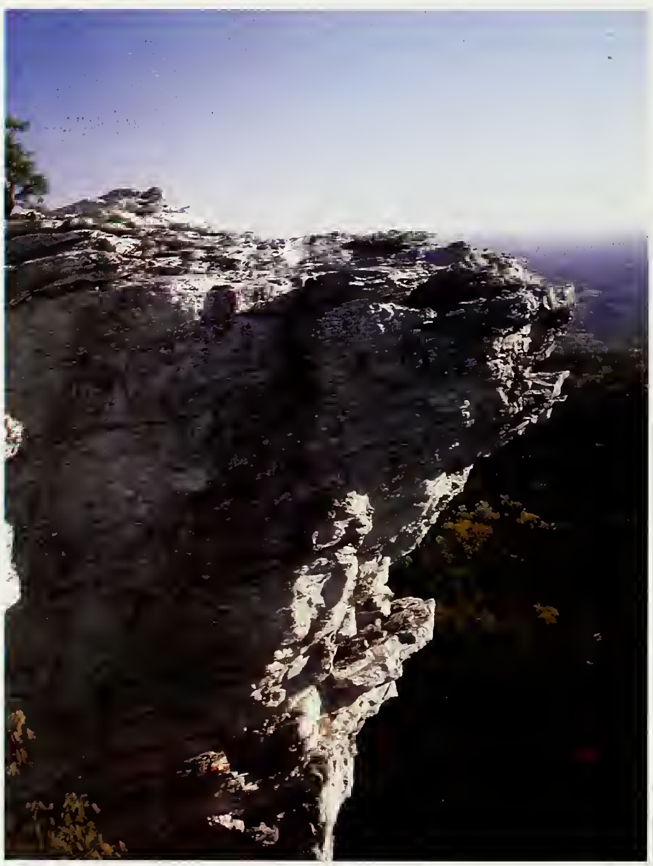
Pyroclastic rock.

HANGING ROCK STATE PARK

Hanging Rock State Park is located in Stokes County, approximately 32 miles north of Winston-Salem and 4 miles southwest of Danbury. The 6,000 acre park is in the northwestern portion of the Piedmont physiographic province.

GEOLOGY

The park lies within an area known geologically as the ***Sauratown Mountains anticlinorium***. The ***anticlinorium*** is an area where the rocks were arched upward. About one billion years ago silt, sand, and clay washed into a sea environment. Layer upon layer of sediment accumulated and was later changed by heat and pressure (***metamorphism***) to the metamorphic rocks we see today. Volcanic rocks were deposited in some parts of the basin. Approximately 700 million years ago hot molten rock (***magma***) invaded the sediments and then cooled to form granite. Gradual uplift and erosion exposed the rocks at the surface, where the action of erosion and weathering carved the rocks into their present appearance.



Hanging Rock.

Features of the original shallow-water environment are now evident in the ***quartzite*** that forms the peaks in Hanging Rock State Park. The quartzite (metamorphosed sandstone) contains horizontal bedding, and in places, cross-bedding, where quartzite beds are aligned at an angle, one to another. Cross-bedding forms where currents or winds carrying sand change direction. Layers of sand accumulate on top of each other oriented at different angles. Cross-bedding in the park formed in a nearshore or beach environment.

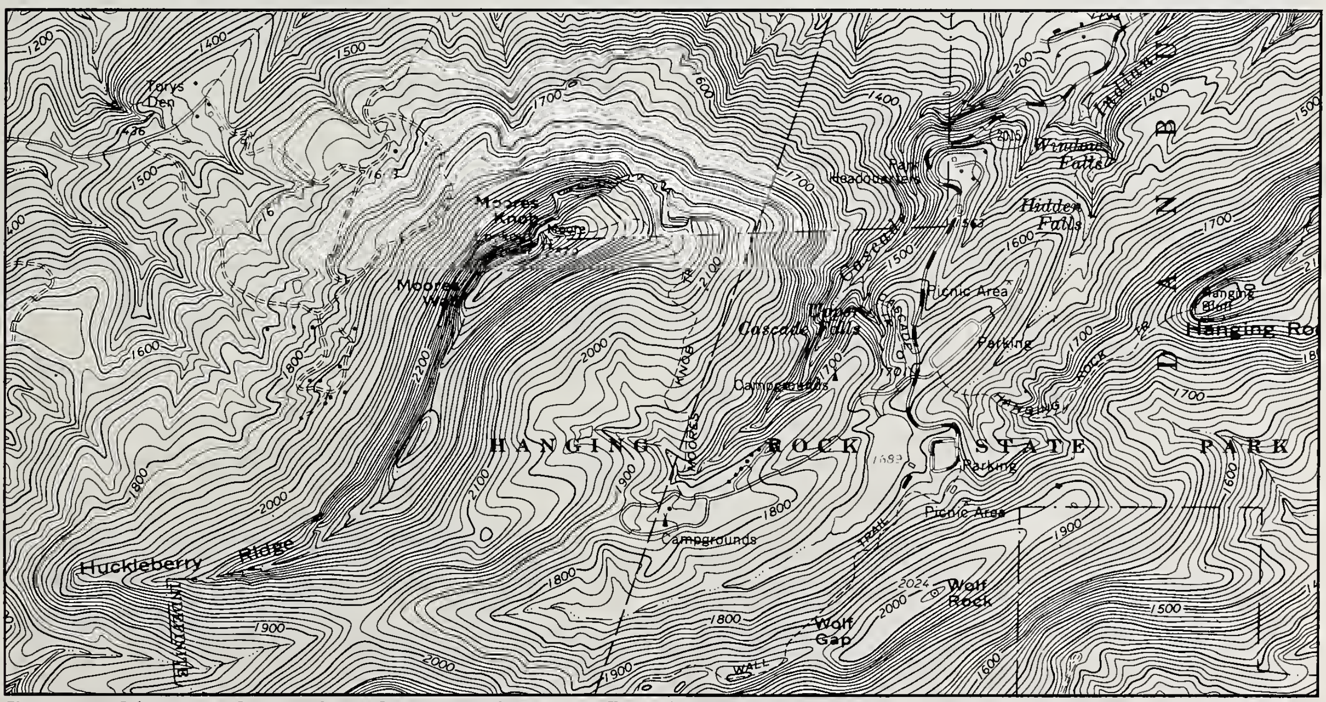
The main geologic features in the park are formed by outcrops of quartzite. Because the 200-foot thick quartzite is more resistant to erosion, this layer of rock formed a protective cover that now caps and supports the scenic ridges and knobs of ***Moore's Knob***, ***Moore's Wall***, ***Cook's Wall***, ***Devil's Chimney***, ***Wolf Rock***, and ***Hanging Rock***. The quartzite also forms the ridge line of the Sauratown Mountains. The Sauratown Mountains are sometimes called "the mountains away from the mountains" because of their close proximity to the Blue Ridge Mountains, only 27 miles northwest, across the valley of the Dan River. Pilot Mountain is also formed by the quartzite.

TRAILS

Hidden Falls Trail - This steeply descending, winding trail is only 0.4 mile long, but its short length is deceiving because of the unique outcrops. Light-gray to tan, sparkling micaceous quartzite beds form a step-like trail that leads to a cascading waterfall, hidden from view until the last turn of the trail. Picturesque ***Hidden Falls*** is a cascading waterfall that plunges over a bedded quartzite scarp and then cascades over the quartzite beds at its base. The water then flows into a stream channel filled with quartzite boulders and large blocks that were eroded from the face of Hidden Falls scarp. These blocks were broken away by running water and ice wedging along the flat surface of the quartzite.

After retracing the path only a short distance, it is possible to continue to follow this trail to the most appropriately named ***Window Falls***. Just before the descent to view the falls, there is a large quartzite outcrop on the right. The white quartz veins were injected along the horizontal bedding planes of the quartzite and lie parallel to each other. This quartz was forced into the quartzite millions of years ago, the last time the rock was deformed. ***Hydrothermal*** (hot water) solutions were injected under pressure along the horizontal bedding planes of the quartzite. Upon cooling, silica precipitated out of solution and solidified as quartz veins. The "window" probably developed as rain water and creek water filled fractures (***joints***) and bedding surfaces in the quartzite. Then, because of freezing and thawing, the quartzite blocks were pushed apart, forming a hole or "window". By carefully looking upstream from the ledge of the "window", it is possible to see Window Falls as it cascades and falls from the face of the bedded quartzite scarp.

Lake Trail - A trail extends from the Family Camping Area, winding down to a 12 acre manmade lake. Several geologic features occur along this densely wooded trail. Three hundred to four hundred feet down trail, an ***artesian spring*** flows across the trail. Groundwater, under artesian pressure, flows from joints and fractures within the underlying mica-rich quartzite. Further down trail, a large rounded outcrop of quartzite is on the south side of the trail. The curved appearance or spherical shape forms as fractures, joints, and horizontal bedding planes within the quartzite begin to weather concentrically, forming rounded surfaces where angular surfaces once existed. This weathering process is known as ***spheroidal weathering***.



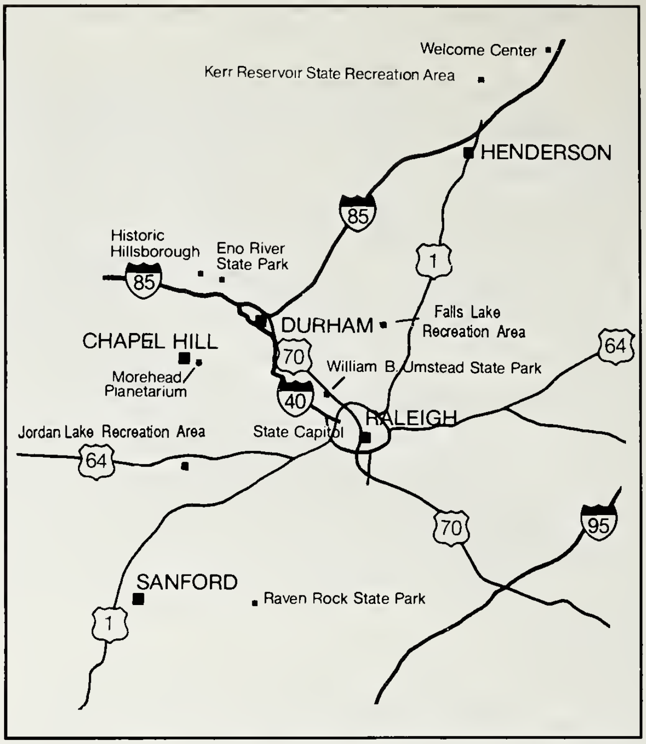
Topographic map of a portion of the Hanging Rock 7.5 minute quadrangle. The numbered lines are contour lines. Each point along a line has the same elevation above sea level. The land surface is steepest where contours are closest.

PIEDMONT RESERVOIRS-STATE RECREATION AREAS

In the eastern Piedmont, the Division of Parks and Recreation manages ***Recreation Areas*** at three large reservoirs: ***Falls Lake, Jordan Lake***, and ***Kerr Lake***. These recreation areas provide a variety of recreational activities including boating, camping, fishing, hiking, hunting, picnicking, swimming, and white water canoeing. Rocks exposed along the shoreline of the reservoirs provide the opportunity to observe the varied geology of the eastern Piedmont.

The reservoirs are located in the eastern Piedmont physiographic province. They are in three major geologic areas, the Carolina slate belt, the Raleigh belt, and the Durham Triassic basin. All major rock types (igneous, metamorphic, and sedimentary) are represented in the recreation areas. Rocks in this portion of the Piedmont formed from sediments deposited in an inland sea or basin between 520 and 800 million years ago. Sediments were washed into the sea and, at the same time, nearby volcanoes ejected volcanic rocks and debris into the basin. These rocks were later deeply buried and altered by heat and pressure (***metamorphism***)to form the metamorphic rocks, ***gneiss*** and ***schist***, we see today. Approximately 240 to 435 million years ago, hot molten rock, ***magma***, intruded the sedimentary and volcanic rocks and solidified to form ***igneous intrusive rocks*** such as ***granite***. Some of the intrusive rocks were also altered by metamorphism.

During the ***Late Triassic Period***, about 220 million years ago, strong forces within the earth's crust pulled apart rocks along the east coast of the United States. This was the beginning of the formation of the Atlantic Ocean as sea floor spreading and continental drift separated the continents. These forces caused some large areas to drop down in relation to surrounding areas that were mountainous at that time. Long, narrow basins were formed in the crystalline rocks along the east coast, including North Carolina. As rivers began to wash clay, sand, and cobbles into the



narrow troughs, layer after layer of clay, sand, and gravel gradually accumulated. Lakes also formed in the basins. Thousands of feet of sedimentary rocks now fill the ***Triassic basins***. Erosion for millions of years has exposed both the metamorphic rocks and the Triassic sedimentary rocks at the earth's surface.

Portions of Falls Lake and Jordan Lake lie within the ***Durham Triassic basin***. A major fault, the Jonesboro fault, forms the eastern boundary of the basin. This fault is the break in the earth's crust where rock to the west dropped down. It separates unmetamorphosed Triassic sedimentary rocks from metamorphosed rocks of the Piedmont. Rock exposures in the recreation areas are usually best exposed along the lake shore during periods of low water level.

FALLS LAKE RECREATION AREA

Falls Lake is located in Durham, Granville, and Wake Counties about 12 miles north of Raleigh and 5 miles east of Durham. The lake extends for about 22 miles up the Neuse River from the town of Falls in northern Wake County. It covers 12,490 acres when contained at its conservation pool level of 250.1 feet above mean sea level. Recreational areas and trails are being established through a series of multi-year projects. A trail along the south shore of the lake will be a part of the ***Mountains-to-the-Sea Trail*** project. This project will eventually result in a hiking trail extending from the mountains to the coast.

Falls Lake lies within two geologic provinces, the ***Raleigh belt*** and the ***Durham Triassic basin***. All three major classifications of rock, ***igneous***, ***metamorphic***, and ***sedimentary***, are in the recreational area. The northwest half of the lake lies within the Durham Traissic basin. Rock types include ***fanglomerate***, ***conglomerate***, and finer grained rocks ranging from ***sandstone*** to ***mudstone***. ***Fanglomerate*** is a very coarse rock composed of large angular fragments of other rocks. This rock formed along the eastern boundary fault (Jonesboro fault) as streams washed debris down the steep slopes and formed alluvial fans. Also along this narrow zone is ***conglomerate*** which contains rounded rock fragments. The conglomerate represents material that was deposited by streams that smoothed the large rock fragments as they were carried downstream. The ***sandstone*** and ***mudstone*** were deposited away from the steep border of the basin where the streams were moving more slowly.

East of the Durham Triassic basin are metamorphic and igneous intrusive rocks of the Raleigh belt. The metamorphic rocks are both light-colored (felsic, quartz-rich) and dark-colored (mafic, quartz-poor) ***gneiss*** and ***schist***. Dark-colored igneous intrusive rocks are also scattered in the area. The igneous rocks include ***diorite***, ***gabbro***, and altered ***ultramafic*** (iron-rich) rock. Ultramafic rock includes ***soapstone***, and many years ago this was quarried nearby for use as building stone.

B. EVERETT JORDAN LAKE RECREATION AREA

B. Everett Jordan Lake is approximately 25 miles west of Raleigh. It is formed by an earth and rock fill dam built by the U.S. Army Corps of Engineers to impound water on the Haw River and New Hope Creek. The project serves multiple purposes of flood control, water supply, water quality control, outdoor recreation, and fish and wildlife conservation. The Division of Parks and Recreation operates numerous recreation areas along the 150 miles of shoreline.

The lake is almost entirely within the Durham Triassic basin. Sedimentary rocks exposed occasionally along the shoreline are sandstone, mudstone, and conglomerate. Triassic rocks yield important quantities of clay for use in the brick and tile industry. Mines nearby help North Carolina annually lead the nation in brick production. Farther south in the Sanford Triassic basin, coal was mined prior to 1953. No coal has been found in the Durham Triassic basin. Oil test wells show small amounts of oil and gas, but commercial amounts have not been found. Felsic volcanic rocks of the Carolina slate belt occur in the southern lake area.

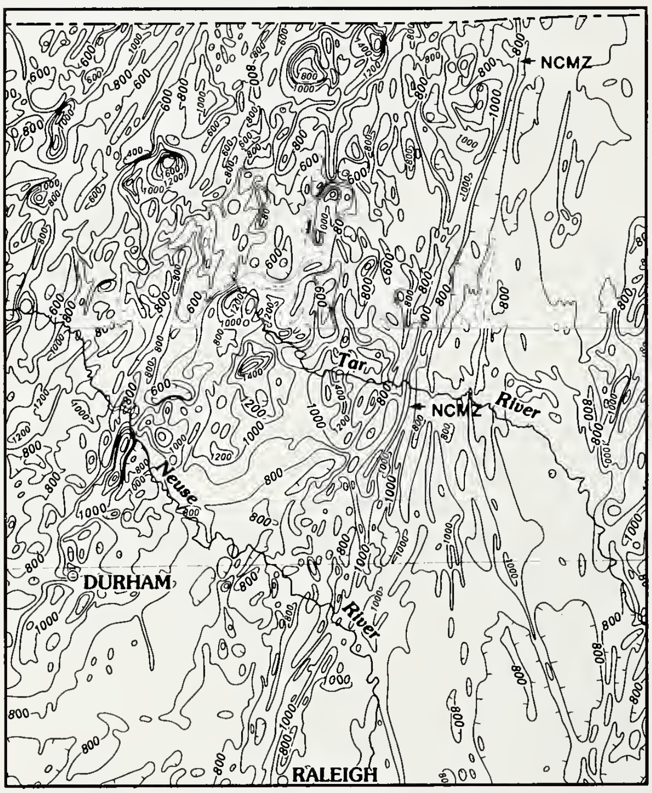
KERR LAKE RECREATION AREA

Kerr Lake Recreation Area, located in northeastern Warren and northwestern Vance counties, is in the northeastern North Carolina Piedmont adjacent to the North Carolina - Virginia State line. Gently rounded hills with moderate slopes form the shore line of this 16,300 acre manmade lake. Kerr Lake's seven recreational areas are on peninsulas, some of which protrude into Kerr Lake for over one mile. These recreation areas are located between 5 and 25 miles north of Henderson, North Carolina.

The Kerr Lake Recreational Area is located in a geologic belt known as the ***Raleigh belt***, an area composed primarily of ***metamorphic rocks*** and ***igneous intrusive rocks***. The main metamorphic rock types at ***Kimball Point*** and ***County Line*** Recreation Areas are interlayered ***biotite gneiss***, ***felsic gneiss***, and ***hornblende gneiss***. ***Gneiss*** is an old German word that originated among the early miners in the Saxony. It was loosely used to include all coarse-grained banded rocks.

Biotite gneiss is more abundant than the other two rock types, and is composed of the minerals ***biotite mica***, a black mica that occurs as thin tabular hexagonal crystal forms; ***muscovite mica***, a colorless to light-green mineral; ***quartz***; and two varieties of feldspar minerals, ***microcline*** and ***plagioclase***. In outcrop, the biotite gneiss has a dark and light banded or layered appearance. The darker bands or layers range in thickness from less than an inch to over four feet; however, most are only a few inches thick. This banded appearance is caused by variations in the amount of biotite mica from layer to layer.

The ***felsic gneiss*** is light in color, uniform in appearance, and contains the minerals muscovite mica, quartz, and plagioclase feldspar. The ***hornblende gneiss*** is not as common in outcrop as the two previously mentioned gneisses. The physical appearance of this rock type is unusual because the black hornblende mineral and feldspar are aligned parallel to each other giving this rock a "striped" appearance.



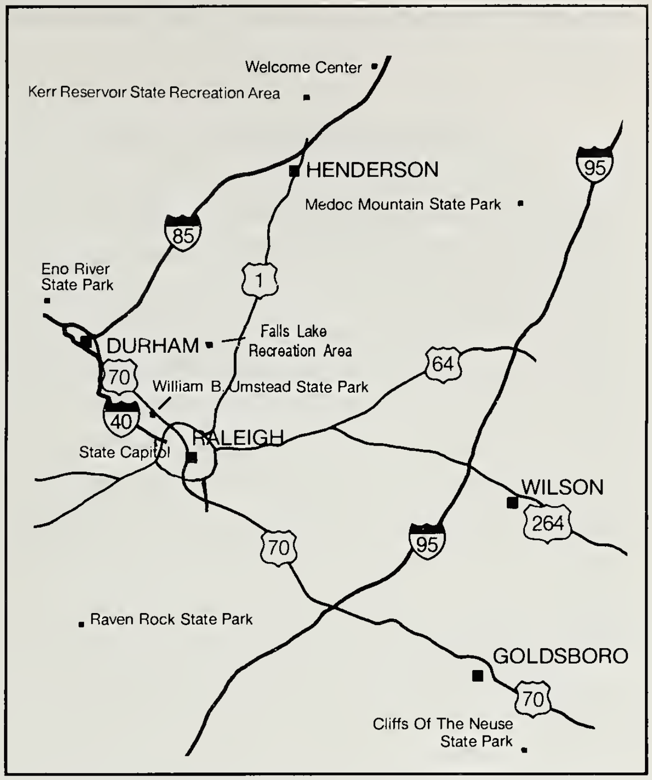
Aeromagnetic map showing the trend of the Nutbush Creek mylonite zone (NCMZ). The numbered lines are contours that indicate the magnetic intensity in gammas along the line.

A zone of deformed or sheared rock, called the ***Nutbush Creek mylonite zone***, is exposed at ***Henderson Point*** and trends in a southwesterly direction through ***Bullocksville*** and ***Satterwhite Point*** Recreation Areas. This relatively narrow, steeply inclined fault zone separates the Raleigh belt from the Carolina slate belt. Mica gneiss east of the fault zone moved both vertically and horizontally in relationship to granite west of the zone. Rocks within the zone have been deformed into new rocks called ***phyllonite*** and ***mylonite***. The original minerals were crushed, broken, and stretched out into thin layers. Some of the rock surfaces contain small mica flakes that give the rock a shiny appearance.

The fault zone stands out as nearly a straight line on aerial photographs. Creeks, such as Nutbush Creek, follow the trace of the zone because, in some places, rocks in the zone are less resistant to erosion. In other places, the rocks are harder than the surrounding rocks and form long ridges. By measuring the magnetic properties of rocks in this area, the zone can also be traced on aeromagnetic maps. (Refer to figure in the opposite column.)

West of the Nutbush Creek mylonite zone, the metamorphic rocks were intruded by molten rock called ***magma*** that crystallized at depth to form granite. Some of the granite was emplaced 650 to 520 million years ago. The granites can be seen in outcrop at Bullocksville and Satterwhite Point Recreation Areas.

MEDOC MOUNTAIN STATE PARK



Medoc Mountain State Park is in southwestern Halifax County 27 miles northeast of Louisburg and 18 miles southwest of Roanoke Rapids. The park is located along the ***fall line***, a narrow zone which marks the boundary between hard, resistant rocks of the Piedmont and softer rocks of the Coastal Plain. The Piedmont rocks here are part of the Eastern slate belt and were formed when volcanic and sedimentary materials were deposited some 500 to 800 million years ago. These materials were deeply buried and changed by heat and pressure to form metamorphic rocks such as ***gneiss***, ***schist***, ***metavolcanic rock***, or ***metasedimentary*** rock. The Piedmont rocks also include masses of granite which forced their way into the metamorphic rocks from below as molten masses (***magma***). The Piedmont rocks were very slowly lifted up and then eroded by the action of rivers and weathering processes to form the present day land surface.

In the northeastern Piedmont, many of the ridge tops were flattened by erosion and capped with thin layers of sand and gravel. The sand and gravel layers are much younger than the underlying Piedmont rocks, and are probably "only" a few million years old. They were laid down and left behind by streams and rivers as they cut down into the Piedmont surface.

The rolling topography of the Piedmont gradually gives way to the flat Coastal Plain just east of the Park area. The Coastal Plain is made of layer upon layer of sedimentary deposits such as sand, clay, marl, and limestone that range in age from tens of thousands of years to over 100 million years. These sediments were laid down by ancient rivers flowing across the Coastal Plain and in the shallow seas that formed as the ocean moved back and forth across the continental margin. Such changes in sea level resulted from gradual sinking of the land and from freezing and thawing of the Earth's polar ice caps. Marine deposits are found as far as 200 miles inland from our present day coastline and at elevations several hundred feet above present day sea level.

The Coastal Plain sediments form a wedge-shaped mass that overlies crystalline rocks like those of the Piedmont. This wedge thickens from a "feather edge" at the ***fall line*** to a maximum thickness of nearly 10,000 feet at Cape Hatteras.

GEOLOGY

Medoc Mountain and adjacent ridge tops are underlain by a granite mass that is about 300 million years old. The granite is composed of the minerals ***feldspar***, ***quartz***, and ***mica***. Quartz ***veins*** are found in the granite and the surrounding metamorphic rocks. Quartz veins are not found in the Coastal Plain sedimentary rocks; so, we know that the veins formed before the sediments but later than the Piedmont rocks. The veins are sheet-like bodies that moved as hot liquids into fractures and zones of weakness in the surrounding rocks. As the liquid cooled, silica precipitated out and formed quartz veins. Quartz is very resistant to chemical decay or weathering. The plentiful quartz lying on the surface of the ground, referred to as ***float***, indicates that quartz veins are just beneath the surface.

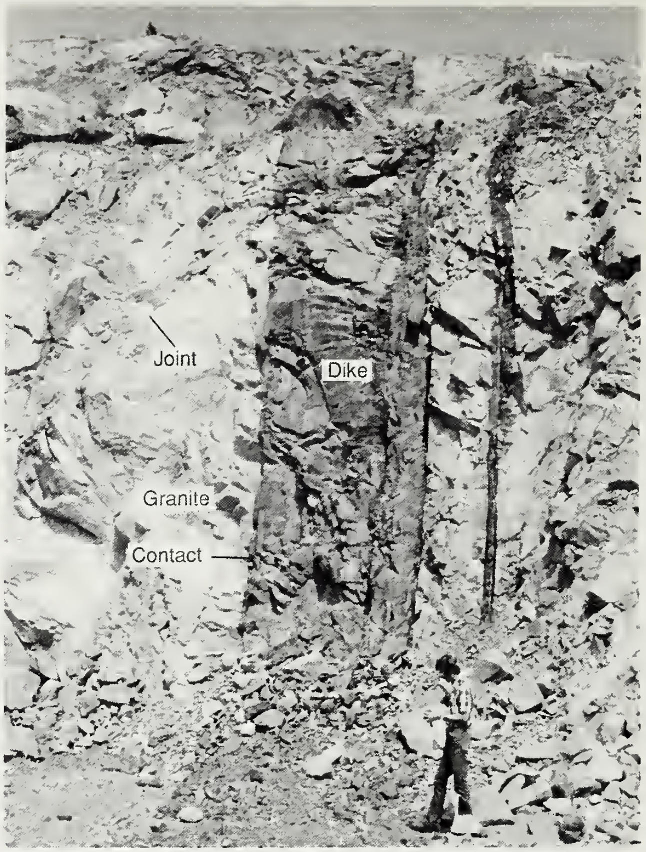
The Medoc Mountain area is significant to geologists because it is the site of a metallic mineral occurrence. ***Molybdenite*** (MoS_2), a mineral that contains molybdenum, was found at this site in 1936. Molybdenum is a metal valued as an alloy because of its high strength and low weight properties. The deposit was explored off and on by private firms and government agencies until about 1970. The United States Bureau of Mines conducted a sampling and core drilling investigation during and after World War II as part of a program to discover and evaluate strategic minerals. Although this is one of the largest molybdenum deposits known in the southeastern United States, it is small compared to deposits mined in the western United States and was never mined.

Molybdenum occurs in the Park as the mineral ***molybdenite*** (MoS_2), a steel blue or silver-colored flaky mineral found in some quartz veins and in portions of the granite. The brass colored mineral ***pyrite*** (FeS_2), or ***fools gold***, is often found with molybdenite.

TRAILS

Summit Trail - This 3 mile loop trail originates at the Park Office and includes Little Fishing Creek and the "peak" of Medoc Mountain.

Quartz float can be seen along the trail as it winds down the slope to the creek. As the slope becomes steeper, blocks of dark colored, fine-grained rock are scattered along the surface of the trail and in the adjacent woods. This rock is a type of igneous rock called ***diabase***. The blocks can be traced in a straight line and indicate that the rock is a sheet-like, vertical feature a few feet wide known as a dike. Diabase dikes intruded rocks in the Piedmont approximately 200 million years ago when North America and Africa drifted apart to form the Atlantic Ocean.



A nearly vertical diabase dike cross-cuts granite in a rock quarry. The dike is 10 feet wide.

Geologists measure the magnetic intensity of rocks in order to study rocks that cannot be seen at the Earth's surface. Because diabase contains a relatively large amount of the magnetic mineral magnetite, it is usually seen as a magnetic "high" on magnetic maps. This enables geologists to map rocks even though the rocks are not visible at the surface. Magnetic maps are also useful in mineral exploration and interpreting the structure of rocks.

Farther along on Little Fishing Creek, a large outcrop of granite rises adjacent to the trail. The granite is cut by numerous quartz veins. ***Molybdenite*** and ***pyrite*** are visible in a few of the veins. Look for areas where the quartz has a yellowish stain on its surface. The stain is an oxide or weathering by-product of the molybdenite. The reddish coating on much of the outcrop is similarly formed by the weathering of pyrite and other minerals containing iron.

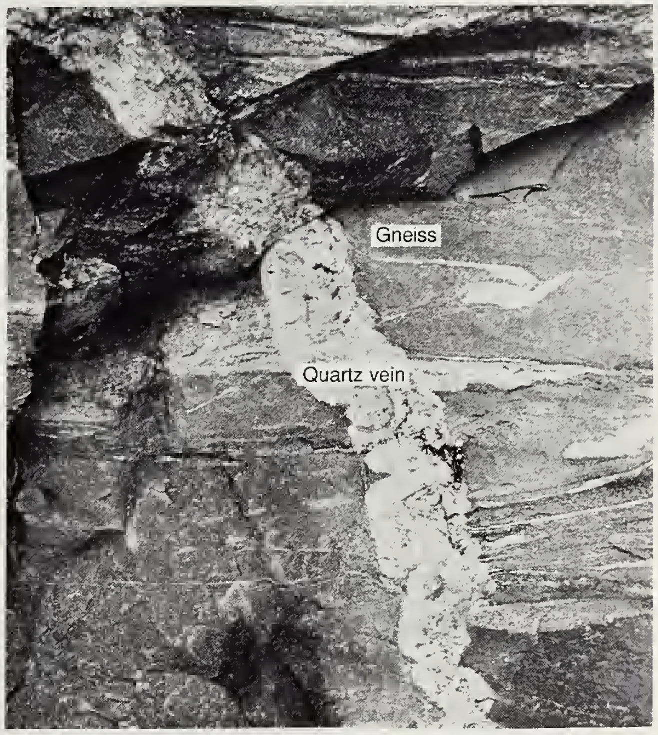
Near the base of Medoc Mountain, red-stained quartz float is abundant. Some of the quartz has a honeycomb texture. The open spaces result from the weathering of pyrite that once filled the spaces. The size of the quartz boulders along this segment of the trail, and along the road leading south from the peak, indicate that some of the veins may be as large as several feet thick.

Dam Site Loop - The Dam Site Loop is a 1-mile long trail that follows Little Fishing Creek a short distance upstream from the sharp bend. Along this trail, Little Fishing Creek bends sharply where the creek encounters the granite that forms Medoc Mountain. The granite, reinforced by the many quartz veins, deflected the stream from its easterly course to one that is southerly along the western edge of the granite.

Where the tributary enters Little Fishing Creek a mound of gravel, called a ***gravel bar***, has built up near the north bank of Little Fishing Creek. Gravel bars form in streams and rivers where the water slows down and the water flow is too weak to carry the sand and gravel. This commonly occurs on the inside of bends or where a tributary enters a larger stream.

Bluff Trail - The Bluff Trail is a 3-mile long trail that originates at the picnic shelter on the east side of Little Fishing Creek. Where the trail climbs the bluff on Little Fishing Creek, there are good exposures of metavolcanic rock. In places along the top of the bluff, soft, flaky material lies on the surface. The flaky material is float from a mudstone that is interbedded with the metavolcanic rock. Both types of rock are exposed at the south end of the bluff where the trail descends back to river level. The outcrop here is also cut by a few quartz veins. Along the hilltops, rounded pebbles and cobbles of quartz are on the surface. The cobbles and pebbles are from a gravel deposit that caps the hill crossed by the trail. The pebbles and cobbles along the trail have very gradually moved down the slope by a process known as slope wash. During this process gravity slowly moves the cobbles down hill as erosion washes away fine-grained material around the cobbles.

Stream Trail - The Stream Trail (3 miles long) originates at the picnic area. Rock exposures are difficult to find along the Stream Trail. This is because the ***bedrock*** was cut away by the erosive action of Little Fishing Creek, and silt, sand, and clay were deposited in its place. One bedrock exposure is in a ravine in the beginning portion of the trail. The outcrop is of metavolcanic rock which has broken or fractured along planes called ***joints***. Note the parallel nature of the joints. There are two main directions of jointing. One direction is to the northeast and the other direction is to the northwest. By studying measurements of the joint directions, geologists are able to understand the forces that caused the rock to fracture. This helps them interpret the geologic history of the area.



A vein cuts across folds in gneiss, indicating that the folding occurred before the vein formed.

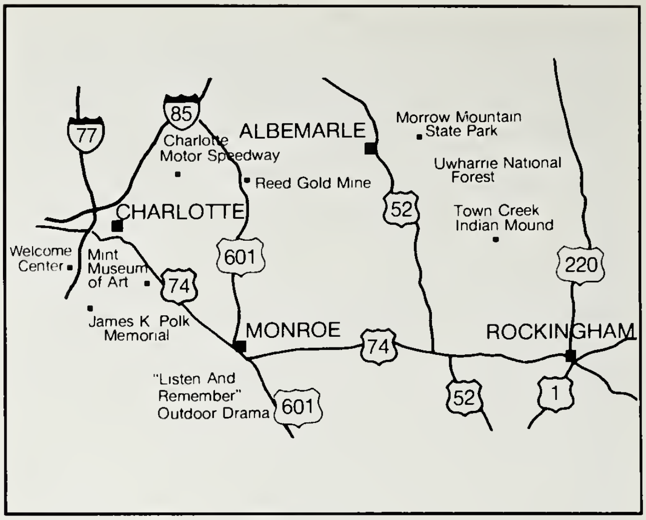
MORROW MOUNTAIN STATE PARK

Morrow Mountain State Park is in .the south-central Piedmont, approximately 5 miles east of Albemarle in eastern Stanly County. It is on the western edge of the Uwharrie Mountains, a low range of hills in Montgomery, Randolph, and Stanly Counties. The Yadkin River forms the northern park boundary, and joins with the Uwharrie River to form the Pee Dee River. The Pee Dee River and Lake Tillery form the eastern park boundary. Elevations in this 4,641 acre park range from a maximum of 936 feet on Morrow Mountain to a minimum of 280 feet along the Pee Dee River.

GEOLOGY

Morrow Mountain State Park lies within the ***Carolina slate belt***, a belt of slightly metamorphosed volcanic and sedimentary rocks that extends from central Georgia to central Virginia. Approximately 600 million years ago this area was part of a chain of volcanic islands surrounded by a shallow sea. Today, we see only the rocks remaining from the hot volcanic eruptions and the layers of sediment deposited in the sea. At the end of the volcanic activity, the layers of ash, lava, and sediment were deeply buried, folded, tilted on edge, and, finally, exposed at the earth's surface. The harder volcanic rocks eroded slowly and form the mountain peaks in this area and in most of the Uwharrie Mountains. The softer sedimentary rocks weathered more easily and underlie many stream valleys.

Three principal rock types are recognizable in the park. These are ***rhyolite***, ***basalt***, and ***argillite***. ***Rhyolite*** is a very hard, dark gray, volcanic rock underlying most of the ridges and hills. It was once thought that this rock formed a cap on the hilltops, but geologists now know that the rock is interbedded with the surrounding rocks. The rhyolite usually contains small feldspar crystals and frequently has wavy ***flow lines*** created as the hot lava and ash flowed from a fissure or down the slope of a volcano.



Basalt is a dark green to greenish-gray rock that is less resistant to erosion than rhyolite. It frequently occurs as rounded boulders scattered over the ground. Basalt is a magnesium- and iron-rich rock, whereas rhyolite contains very little magnesium and iron. Argillite, or mudstone, is a gray rock where it is fresh, weathering to a brown color. It has the appearance of slate but breaks into small chips or blocks. Thin parallel lines or layers in the rock represent bedding planes—layers of mud and silt that were deposited in a shallow sea. The rock is not resistant to weathering, and is usually found in lower elevations and along creeks.

Morrow Mountain State Park is in the heart of what was once a ***major gold-mining area***. The first authenticated discovery of gold in North America was in 1799 at the Reed Mine in Cabarrus County, only 25 miles west of here. Gold mining soon spread to nearby counties, and, until 1828, North Carolina was the only producer of gold in the United States. Mines in the Carolina slate belt were an important part of this production. Although gold has not been produced in recent years, it is possible to pan gold from the Cotton Patch Mine north of Albemarle and in the Uwharrie National Forest east of Lake Tillery. (Check with a park ranger prior to panning in the National Forest.) The possibility of new discoveries continues to lure gold-exploration companies into the area.

Indians occupied this area over 10,000 years ago and established camps for hunting and fishing. Because of its hardness, the rhyolite was used extensively in making stone tools. Indian tribes from other areas came to the Uwharrie Mountains to obtain rhyolite for making tools. These tools are commonly found many miles from the slate belt. This indicates that the Indians covered large areas in search of game, or came to this area to obtain raw materials for tools.

TRAILS

Trails in the park provide an excellent opportunity to observe the major rock types. Many of the trails begin in lower elevations, where argillite or basalt is exposed, and continue across the hilltops, where rhyolite is exposed. Some rock types have sedimentary or volcanic features that can be seen in individual outcrops and rock fragments. The top of Morrow Mountain is the most easily accessible place to view the rhyolite. Fragments of the rock are scattered over the ground. Argillite is common in the picnic area and in the small quarry nearby. Three trails are described here.

Fall Mountain Trail - The trail begins in the flat floodplain of the Yadkin River. A floodplain consists of loose sand and gravel adjacent to a creek or river which floods periodically. Dams on the Pee Dee and Yadkin Rivers help prevent floods in this area.

The trail begins a gradual climb until it finally reaches the summit of Fall Mountain. In the lower elevations the trail passes through areas underlain by ***argillite***. Outcrops are not abundant here, but small chips or fragments of tan and brown argillite are common on the ground surface. Geologists refer to these rocks as ***float*** because they are suspended on the top of the soil. In areas where outcrops are absent, they give good indications of the rocks beneath the surface.

Near the crest of the first low knob, fragments of milky white quartz are scattered over the ground surface. This quartz, also "float" material, was part of a ***quartz vein***. A vein is a sheet-like body which extends down into the ground hundreds or thousands of feet and can be traced in an almost straight line along the earth's surface. Quartz is very resistant to erosion and remains after the rocks around it have eroded away. Fractures in quartz veins provide good avenues for the movement of water and are frequently useful sites for locating water wells. In some portions of the state, gold was found in quartz veins similar to this one. This quartz vein is barren of gold.

Near the top of Fall Mountain, fragments of rhyolite become abundant on the ground. This is the hard, dark-gray volcanic rock found on top of the higher peaks in the park. On the trail down to the Yadkin River, white, milky quartz "float" becomes mixed with the rhyolite. This indicates that a quartz vein is just beneath the surface. Near the bottom of the slope, argillite is exposed.

Near the Falls Dam, hard gray and black ***rhyolite*** contains many small, white feldspar crystals. This rock is similar to the rhyolite found on top of Fall Mountain. Because it is so hard, it forms rapids in the river. The dam is operated by Alcoa and provides power to run the aluminum plant. Approximately 1.3 miles downstream, the Uwharrie River joins the Yadkin River and the two become the Pee Dee River. A one-mile section of the Yadkin River above the dam was once referred to as the ***Narrows***. The river provided a spectacular scene as it narrowed from a width of 1,000 feet down to a width of 60 feet. Total fall of the river from the head of the Narrows to the mouth of the Uwharrie River was 91 feet. An 1899 publication on waterpower in North Carolina describes the Narrows as "one of the most wonderful spots that can be found in the south."

As the trail continues along the river, it passes through ***argillite*** and then into ***basalt***. A large outcrop of basalt forms rounded boulders along the river bank. The basalt has broken along fracture surfaces. Bedded rhyolite is exposed beyond the basalt. Thin parallel lines in the rhyolite are ***bedding planes*** formed by layers of volcanic ash that were deposited on top of one another.

Quarry Trail - The quarry trail makes a loop from the picnic area to a small quarry. The trail provides an opportunity to view good exposures of ***argillite***. Stone from the quarry was used in constructing many bridges, walls, and buildings in the park.

The quarry is a good site for observing ***bedding*** in the argillite. The bedding is inclined at a steep angle, indicating that the rock has been tilted from its original horizontal position. ***Fractures*** developed parallel to the bedding planes and also at angles to it. The size of trees growing in the quarry floor gives an indication of how long it has been since this abandoned quarry was operated.

Sugarloaf Mountain Trail - The trail passes through all rock types occurring in the park. Near the parking area, rounded boulders of basalt and rhyolite are exposed. Farther along the trail, white, milky ***quartz*** boulders are scattered on the surface. The quartz is very resistant and underlies a low knob. These boulders have been left behind as the surrounding rocks weathered away from a quartz vein. The trend of a quartz vein can usually be followed by tracing the quartz "float" on top of the ground.

As the trail ascends, it gradually passes into the hard, light gray ***rhyolite***. After the trail crosses the road to Morrow Mountain, boulders of rhyolite ***breccia*** are visible. These boulders contain angular rock fragments that probably formed as the partially solid lava flowed and broke into fragments.

Near the top of the mountain, the rhyolite has a banded appearance. These wavy layers are ***flow bands*** that formed as the hot rock moved. They look similar to bedding planes but are more undulating in appearance. They are more visible on weathered surfaces than on fresh surfaces. As the trail descends the east side of the mountain, look closely near the base of the mountain for the contact between rhyolite and argillite.

The "Narrows" prior to construction of the Falls Dam. (About 1899)

PILOT MOUNTAIN STATE PARK

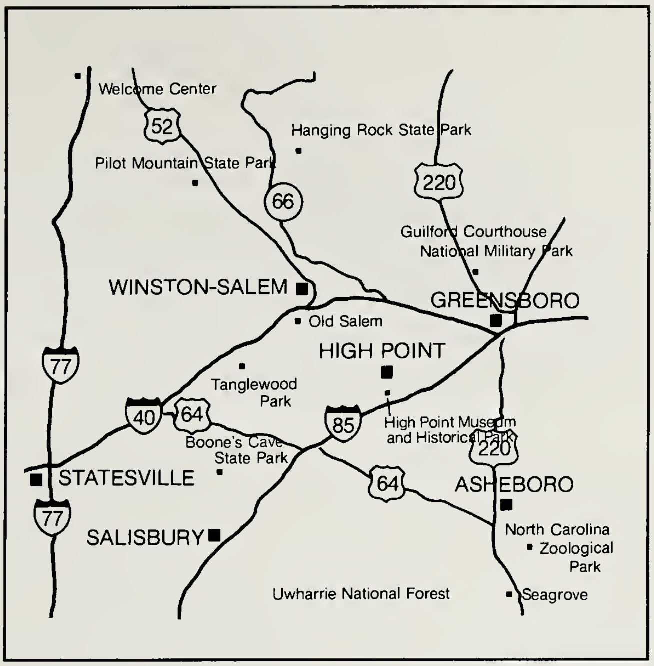
Pilot Mountain State Park is in Surry County, 24 miles north of Winston-Salem. It is easily reached from U.S. highway 52, the most direct and widely-used route to the park. The 3,768 acre park is situated in the northwestern portion of the Piedmont physiographic province and lies in the ***Sauratown Mountain*** range.

GEOLOGY

The park lies within an area known geologically as the ***Sauratown Mountains anticlinorium.*** An ***anticlinorium*** is an area where the rocks were arched upward. Rocks in this area were formed approximately one billion years ago when mud, silt, sand, and clay washed into a sea environment. Layer upon layer of sediment accumulated and was later changed by heat and pressure (***metamorphism***) to the metamorphic rocks visible today. Volcanic rocks were deposited in some parts of the basin. Approximately 700 million years ago hot molten rock (***magma***) invaded the sediments and then cooled to form granite. Pressures within the earth pushed the rocks to the surface where the action of erosion and weathering carved the rocks into their present appearance.

Features of the original shallow-water environment are now evident in the ***quartzite*** that forms the peaks in Pilot Mountain State Park. The quartzite (metamorphosed sandstone) contains horizontal bedding, and in places, cross-bedding, where quartzite beds are aligned at an angle to each other. ***Cross-bedding*** forms where currents carrying sand in shallow water change direction or where wind direction changes on a beach. Layers of sand accumulate on top of each other oriented at different angles. Bedding of this type formed in a nearshore or beach environment.

When deformation of the rocks ceased, the folded rocks and surrounding terrain were then sculptured by erosion to their present outcrop forms. Water in the form of rain, snow, and ice



began to degrade and remove the less resistant gneiss and schist, channeling these sediments into streams and rivers that transported and deposited them further into the Piedmont. Because the overlying 200-foot thick quartzite is more resistant to the effects of erosion, this layer of rock formed a protective cover that now caps and supports Pilot Mountain State Park. The quartzite also forms the ridge line of the Sauratown Mountains, sometimes called ***the mountains away from the mountains*** because of their close proximity to the Blue Ridge Mountains which are only 27 miles northwest, across the valley of the Dan River.

Pilot Mountain is called an ***inselberg*** because it is a prominent peak protruding from the nearly flat Piedmont plateau.

TRAILS

The paved road to the top of Pilot Mountain crosses the geologic contact between two distinct rock types. This contact is between light gray to tan, bedded ***quartzite*** overlying an interlayered sequence of ***gneiss*** and ***schist***. The outcrop displays the weathering characteristics of the rock types. The overlying, more resistant quartzite shows some rounded edges. The underlying gneisses and schists were scoured out through chemical and mineral decomposition, removal of rock by surface water runoff, and by freezing and thawing.

At the parking lot atop Pilot Mountain, the overlooks reveal panoramic views of rounded hills and broad valleys of the surrounding Piedmont plateau. The quartzite crest of ***Big Pinnacle*** (elevation 2,421 feet) rises approximately 1,500 feet above the surrounding Piedmont.

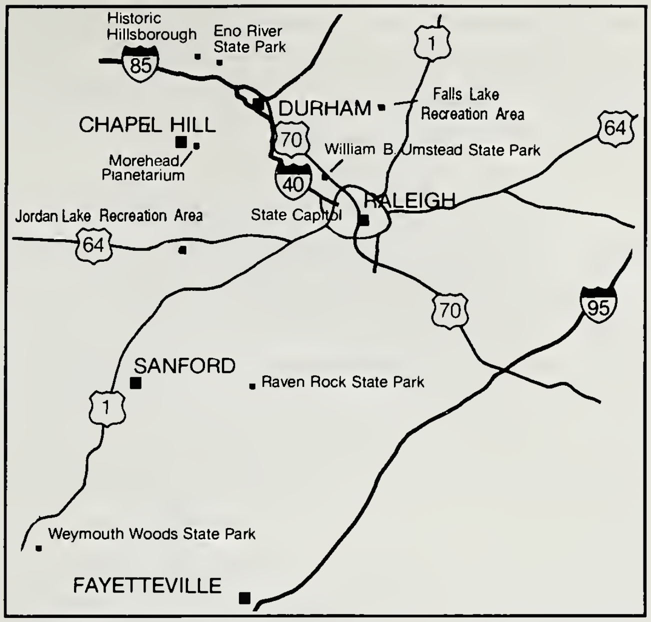
From the parkway area atop Pilot Mountain State Park, visitors can walk southeast toward ***Little Pinnacle***. The little flat step-like surfaces are ***bedding planes*** that mark the tops of individual quartzite beds. Most of the quartzite beds are less than one inch thick. The "sparkles" in the quartzite are tiny flakes or crystals of the mica mineral ***muscovite***. The mica is more evident on sunny days, because the flat surfaces of the mica reflect sunlight. The trace of the axis of the ***Sauratown Mountain anticlinorium*** passes through the gap between Little Pinnacle and Big Pinnacle.

From Little Pinnacle it is a pleasant walk south to the quartzite overlook; the southern view of the Piedmont plateau is spectacular. Also of interest are the ***spherical*** or ***curved weathering*** surfaces of the quartzite. The curved appearance forms as the fractures, joints, and horizontal bedding planes within the quartzite begin to weather in layers, forming rounded surfaces where angular surfaces once existed. This weathering process is known as ***spheroidal weathering***. In places, ***cross-bedding*** is seen. Cross-bedding is particularly well exposed near the base of Big Pinnacle on the southwestern side.

Big Pinnacle with the Sauratown Mountains and Hanging Rock in the background.

RAVEN ROCK STATE PARK

Raven Rock State Park is located on the Cape Fear River in Harnett County, approximately 6 miles northwest of Lillington. The park was established in 1970 in response to local efforts to protect the Raven Rock area from commercial development. The park now includes 2,752 acres along the Cape Fear River.



GEOLOGY

Raven Rock State Park lies near the ***fall line***, a narrow zone marking the boundary between hard, resistant rocks of the Piedmont and softer rocks of the Coastal Plain. Rapids, such as ***Lanier Falls*** and ***Fish Traps***, are common in the principal rivers along this zone.

The Piedmont rocks at Raven Rock were deposited as sediments in a shallow sea 500 million to 800 million years ago. Layer upon layer of sand composed of the minerals ***quartz***, ***feldspar***, and ***mica*** fell to the sea floor and later formed rocks called ***sandstone***. The sandstone was then deeply buried and changed by heat and pressure 300 to 500 million years ago and made into metamorphic rocks called ***gneiss*** and ***quartzite***. Later, the metamorphic rocks were gently arched upward, and exposed at the land surface through the processes of weathering and erosion. Millions of years ago the Cape Fear River, or an older river, deposited layers of gravel and sand on top of the metamorphic rocks. The gravel layers (***terraces***) are visible on the higher ridges in the park, particularly in the picnic area, where rounded, white quartz cobbles cover the ground. These gravels are mined nearby for construction and for decorative stone. The rocks in the park were exposed as the Cape Fear River continued to cut down through the gravels and metamorphic rocks.

The most prominent geologic feature in the park is ***Raven Rock***, named in 1854 for the ravens roosting on the rock ledges. Raven Rock is an outcrop of gneiss rising approximately 100 feet above the river. It was once a choice camp site for Indians. Raven Rock and other rock outcrops on the south side of the Cape Fear River were carved by the erosional forces of the river. The hardness of the gneiss and its resistance to erosion helped create these impressive exposures. In places, river banks are steeper on the south side of the river because of prevailing wind systems, meander development, rock structural controls, and the

Raven Rock.

Coriolis force. The Coriolis force is a principle that states that, as the Earth rotates, streams in the northern hemisphere are deflected to the right, looking downstream.

A closer examination of Raven Rock reveals some interesting geologic features. Notice the lighter and darker colored layers in the rock. These layers represent changes in the composition of the original sediments when they were deposited in the sea. In places, ***quartz veins*** squeezed between the layers of gneiss. The veins originated as hot silica-rich liquids, that cooled and hardened into clear or cloudy quartz. A white mineral, ***feldspar***, and shiny flakes of ***mica*** are also present. Some of the quartz veins are parallel (concordant) to the layers in the gneiss. Other veins cut across (discordant) the layers in the gneiss.

Small amounts of a soft white mineral, called calcite, also occur in Raven Rock. This mineral has the chemical composition calcium carbonate. Geologists frequently use a dilute acid test to identify it. When dilute hydrochloric acid is placed on the mineral, it bubbles (***effervesces***) as CO_2 gas escapes. This is similar to the bubbling effect when vinegar is placed on baking soda.

In places the rock looks blocky, and has one or more surfaces that are flat and straight, giving the appearance of having been cut by a saw. These are ***joint*** surfaces or cracks in the rock which formed as the overlying rock was removed by wind and water (erosion) or when the rock was folded. Usually it is possible to see numerous parallel joints and then other joints at different angles.

The large pile of rocks at the base of Raven Rock represents fragments of rock that have broken off and fallen. Some of the rocks near the river contain holes drilled many years ago when the rock was quarried. These holes were drilled into the rock by machines. Then dynamite was placed in the holes and exploded to break apart the large boulders. Fortunately, the quarrying ceased before Raven Rock was destroyed.

TRAILS

Campbell Creek Loop Trail follows the west bank of Campbell Creek where gneiss similar to Raven Rock is well exposed. The trail begins near the parking area, a relatively flat, upland area underlain by white, rounded river gravel. This gravel is mostly rounded quartz cobbles deposited by the ancestral Cape Fear River millions of years ago. The cobbles were probably carried from the higher Piedmont region and were gradually rounded as they moved along the river bottom during their long journey. Some of the cobbles have a reddish color that is ***iron stain***. As the trail descends and approaches the creek, it winds through metamorphic rocks. Fragments of gneiss along the trail give a hint of the rock beneath the surface of the ground. Fragments of quartz on the ground surface mean that ***quartz veins*** are nearby. Quartz veins are sheet-like bodies which are used by geologists to locate water wells. They act as traps and channels for water to move beneath the land surface. If a well is drilled to intersect a quartz vein, the well commonly provides good supplies of water.

The creek winds through gneiss and large rock exposures are visible in many places. The largest rock, or outcrop, is on the right bank where the creek takes a sharp left turn. Gravel bars occur in the creek where the creek changes direction or at other places where the water flow slows, causing larger, heavier particles of sand and gravel to drop from the water.

Lanier Falls Trail branches from the Campbell Creek trail and follows the slope down to the Cape Fear River. Lanier Falls is a long outcrop of gneiss extending almost across the width of the river.

Fish Traps Trail leads to another long outcrop of gneiss that extends almost across the width of the river. Years ago, Indians placed baskets below the rocks and trapped fish as they swam upstream.

SOUTH MOUNTAINS STATE PARK

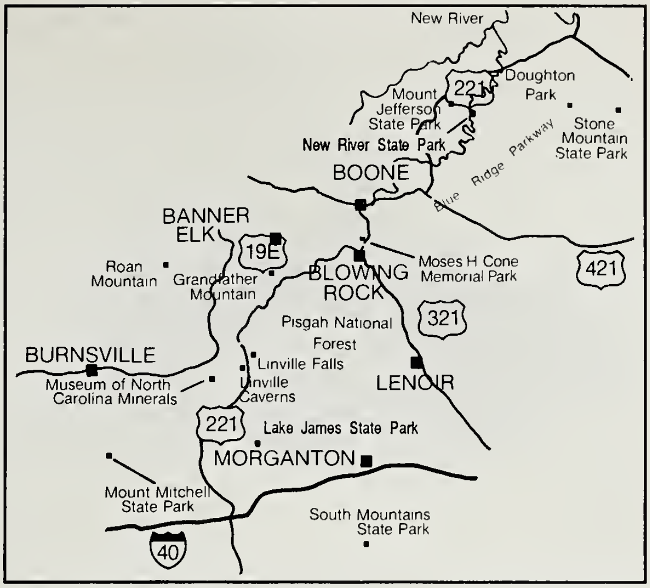
South Mountains State Park is in the western Piedmont physiographic province, 18 miles south of Morganton and 30 miles north of Shelby. The park is in the South Mountain range, a northeast-trending spur of the Blue Ridge Mountains. Elevations in the park range from a high of 2,890 feet on Benn's Knob to a low of 1,250 feet along Jacob's Fork River.

The park is characterized by mountain streams and ridges that provide good exposures of the rocks. The most outstanding feature in the park is ***High Shoals waterfall,*** which drops 70 feet over bare rock to the stream below. This high Piedmont area forms the headwaters of Jacob's Fork River.

GEOLOGY

The park lies within the Inner Piedmont geologic province. Rocks in this area were originally formed nearly one billion years ago when sediments and volcanic rocks were washed into a sea or basin. These rocks were then deeply buried and intruded by hot, molten magma which later cooled to form igneous rocks, such as granite. The sedimentary, volcanic, and igneous rocks were then altered by heat and pressure (***metamorphism***) to form ***metamorphic*** rocks. Inner Piedmont rocks are primarily ***gneiss***, ***schist***, ***amphibolite***, and ***intrusive*** rocks of ***ultramafic*** to ***felsic*** composition. Metamorphosed granite exposed in the park is named ***Toluca Granite***. Most of the gneisses and schists were contorted and folded by forces deep within the earth which built the Appalachian Mountains. The forces of erosion carved the landscape we see today, slowly weathering the rocks, carrying sediment downstream, and leaving boulder-laden valleys behind. The main rocks in the park are ***muscovite*** and ***biotite gneiss*** and ***schist***, ***sillimanite schist, and granite gneiss*** (***Toluca Granite***).

Outside the park in Burke, McDowell, and



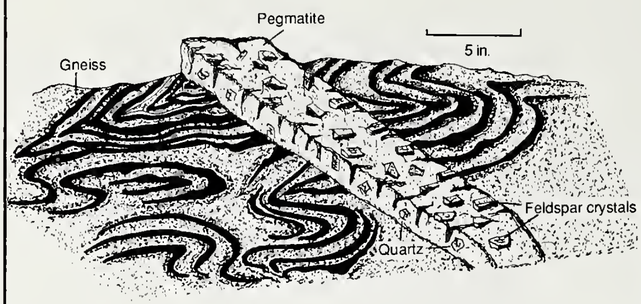
Rutherford Counties, ***gold*** was mined from about 1828 until the mid 1900's. Much of the mining was from stream placer deposits along Brindle, South Muddy, North Muddy, and Silver Creeks and along the First and Second Broad Rivers. A few vein deposits were also worked. Gold is not mined from this area today and ***does not*** occur in the park.

Monazite, a mineral that contains rare-earth elements, also occurs in streams outside the park. It was mined in the late 1800's, but there has been no production since 1910.

Three ***diamonds*** were found in stream gravels near Dysartsville, McDowell County, and two were found in Rutherford County. Diamonds are usually associated with rocks called kimberlites and lamproites, but these rocks have never been found in this area. The primary source of the diamonds has never been discovered.

FALLS TRAIL

Falls Trail leads up Jacob's Fork River to ***High Shoals Falls***. In the lower part of the valley, the rock is well layered and contains many layers of ***schist***. Farther up the valley, the rock is more massive and contains more quartz and less mica. Many interesting geologic features are on the trail after it crosses Shinny Creek. To the right of the



Pegmatite dike in gneiss. Since the pegmatite contains large amounts of coarse quartz and feldspar, it is more resistant to weathering than the gneiss and stands up in relief. This weathering process is differential weathering.

trail, a large block of granite gneiss (Toluca Granite) has broken and fallen. The block broke along a straight, flat surface called a ***joint*** plane. Joints are fractures that formed millions of years ago when the rocks were deformed or when stress was released as overlying rocks were eroded away. Layers of different minerals are exposed where the rock broke and reveal a coarse, white rock called ***pegmatite***. The pegmatite formed during the last stages of igneous activity. It squeezed into the rock parallel to the layers in the granite gneiss.

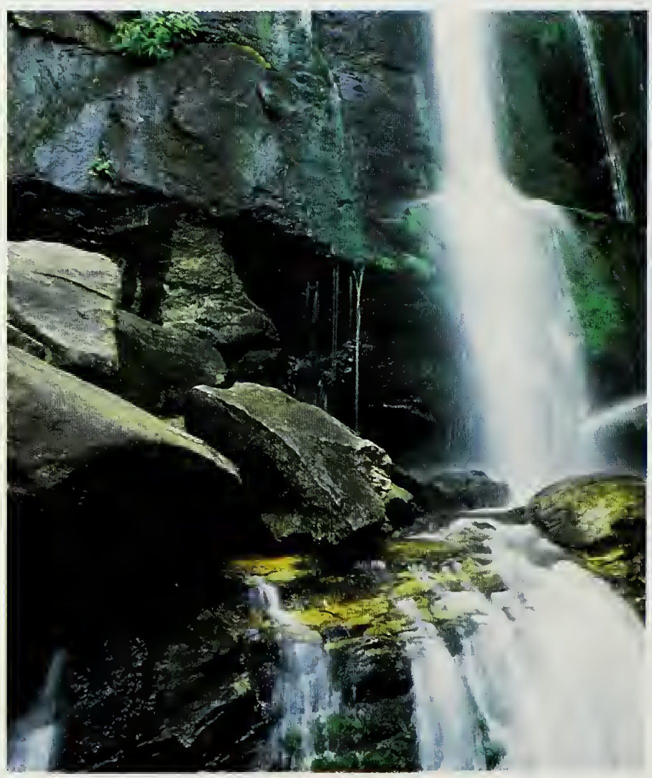
Farther along the trail, closely spaced joints in the Toluca Granite make the rock look as if it had been cut by the park rangers to form steps. These blocks formed by natural processes and fell from the sides of the valley. A large ***debris slide*** along the right side of the trail shows how these large blocks can move with great force down the valley. Many of the large boulders in the creek probably got there in this manner.

Narrow, straight lines cross the surfaces of the large boulders in the creek. These lines are tiny fractures that were filled with a weather-resistant mineral such as quartz. Since the quartz is harder than the surrounding rock, it forms a thin, straight, raised ridge on the rock surface.

Near the falls, a small ***cave*** formed where a slab of rock broke along a joint surface and rested at an angle against the side of the hill. There are not many ***solution caves***, such as Linville Caverns, in North Carolina, but many caves develop from rock movements such as can be seen here.

The climb up the valley is rewarded by a spectacular view of ***High Shoals Falls***. Jacob's Fork River plunges 70 feet down the steep face of Toluca Granite. This surface is also a joint surface. Some of the large boulders below the falls may have broken from the face of the granite. The appearance of the falls changes according to the amount of rainfall in the valley above the falls.

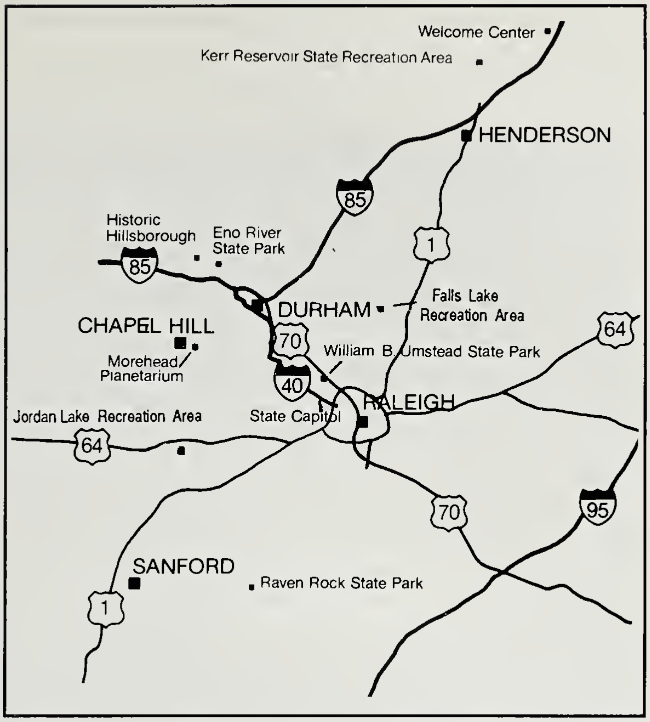
Gneiss and schist crop out along less frequently used trails such as Shinny Trail, Possum Trail, Sawtooth Trail, and Jacob's Branch Trail. As in all state parks, rock collecting is not allowed.



High Shoals Falls.

WILLIAM B. UMSTEAD STATE PARK

William B. Umstead State Park is approximately 5 miles west of Raleigh in the eastern Piedmont physiographic province. The park is the most urban park in the State, with rapid encroachment from Raleigh and Durham. Elevations in the park reach approximately 400 feet, with maximum relief of less than 150 feet. The park is divided into two sections: the Crabtree Creek section and the Reedy Creek section.



GENERAL GEOLOGY

Rocks within the park include igneous, metamorphic, and sedimentary types. The eastern two-thirds of the park is underlain by metamorphic rocks and igneous intrusive rocks that are between the ***Raleigh belt*** and the ***Carolina slate belt.*** The western one-third of the park is underlain by slightly metamorphosed volcanic and sedimentary rocks of the Carolina slate belt. Near the western park boundary, unmetamorphosed sedimentary rocks of the ***Durham Triassic basin*** are exposed.

Raleigh belt rocks were originally deposited as sediments at a continental margin, probably during ***late Proterozoic*** or ***early Cambrian*** time. Rocks in the eastern portion of the park are primarily ***mica schist*** and ***mica gneiss*** intermixed with ***hornblende gneiss*** and ***ultramafic rock.*** They probably were originally deposited as mudstone, impure sandstone, and dark-colored intrusive rocks. ***Volcanic*** and ***sedimentary*** rocks of the Carolina slate belt lie west of these rocks. All of the original sedimentary and volcanic rocks were altered by heat and pressure (***metamorphism***) and folded to form the gneiss and schist we see today.

About 200 million years ago during ***Triassic time***, forces within the earth caused rocks to pull apart along the east coast of North America. Large areas of rock dropped down relative to rocks beside them and created long, narrow basins. These basins were then filled with sediment as rivers rushed over the side of the basins and then slowly meandered through the center of the basin. Up to 7,000 feet or more of sediment was deposited in some areas. The basins were much like the ***rift valleys*** in Africa today. Rocks from the Durham Triassic basin formed in this manner and are poorly exposed along the Western park boundary. The Jonesboro fault forms the boundary between the Triassic rocks and igneous and metamorphic rocks in the park. Fossil evidence indicates that dinosaurs roamed some of the area during Triassic time. Vertebrate fossils found in black shale include fish, amphibians, reptiles, and mammal-like reptiles.

TRAILS

Umstead Park has 17 miles of trails that follow the streams and cross hills forested with pines, hickory, and oak. Rocks are exposed best along the streams where erosion has left the more weather resistant rocks behind.

Good exposures of intrusive rock, called ***granite***, are at the ***Company Mill*** site on Crabtree Creek. Granite is a hard massive rock broken by many smooth, flat surfaces called ***joints.*** The rocks were not cut by man but formed these cracks naturally. Because the joints enable the rock to be stacked closely, granite makes a good dam. An outcrop of granite is on the north side of Crabtree Creek. It is a good, solid foundation for the dam. Joints are also visible in the outcrop.

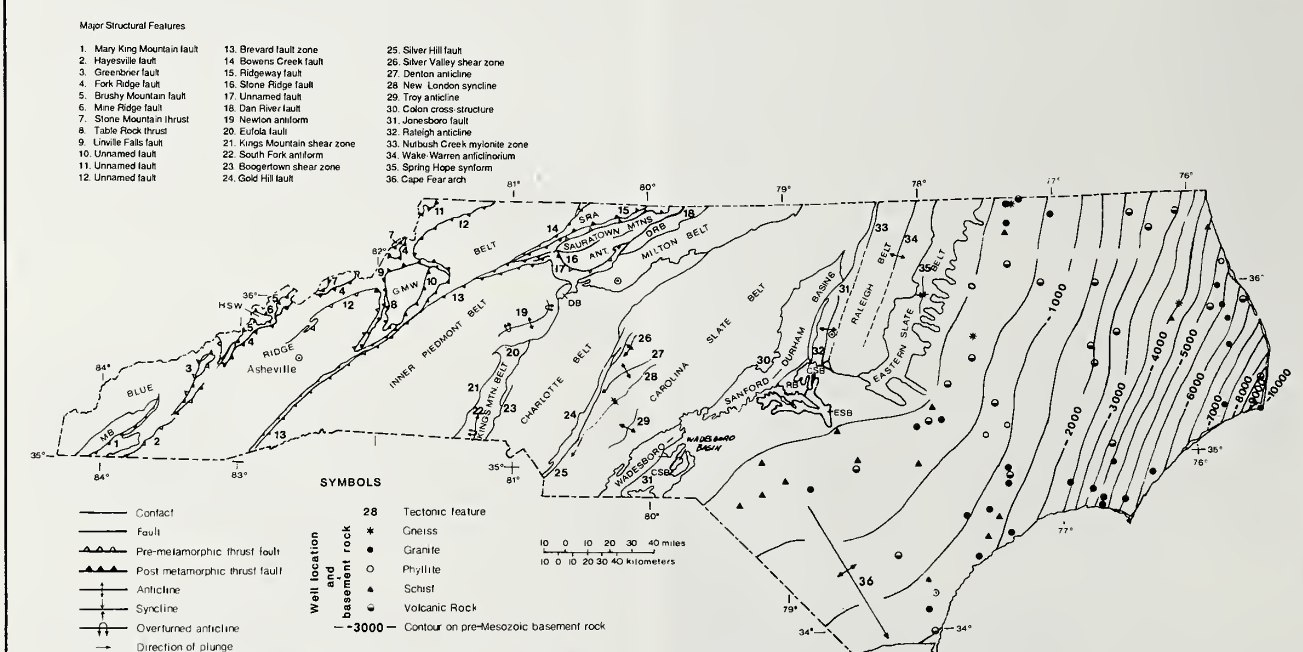
Behind the dam, Crabtree Creek has cut down approximately 15 feet through sediment. When the mill was in operation, sediment carried by the creek slowly filled the bottom of the small lake. When the dam was broken, the creek cut down through the sediment to its original level.

Biotite gneiss is exposed along ***Beech Trail*** between Crabtree Creek and Sycamore Creek. Large boulders of gneiss form the steep valley of Sycamore Creek along ***Dogwood Trail.*** The gneiss is composed of biotite mica, quartz, and feldspar in alternating dark and light layers.

The spillway below Highrock Lake Dam on Sycamore Creek can be reached from the ***Sycamore Trail.*** This outcrop shows excellent exposures of gneiss in contact with ***quartzite***. Small stringers of quartz crosscut both the gneiss and quartzite. This shows that the stringers formed later than both of the rock units. A few fragments of quartzite are in the gneiss, which indicates that the sediments that formed the gneiss were deposited after the sediments which formed the quartzite. Quartzite is also well exposed in the small quarry farther south on Sycamore Trail. ***Quartzite***, as the name implies, is composed mostly of quartz with minor feldspar and mica. It may have been originally deposited as a beach sand. Stone was mined from the quarry during the 1930's for use in the construction of walls, bridges, and buildings in the park.

A quartz-rich gneiss is exposed along the small creek east of the main picnic area. The gneiss contains only a small amount of biotite mica and is much lighter in color than the gneiss along Beech Trail and Dogwood Trail.

Metamorphosed volcanic rocks and Triassic sedimentary rocks are not well exposed in the park. They are poorly exposed along Sycamore Creek near the western edge of the park. No trails lead to this area.

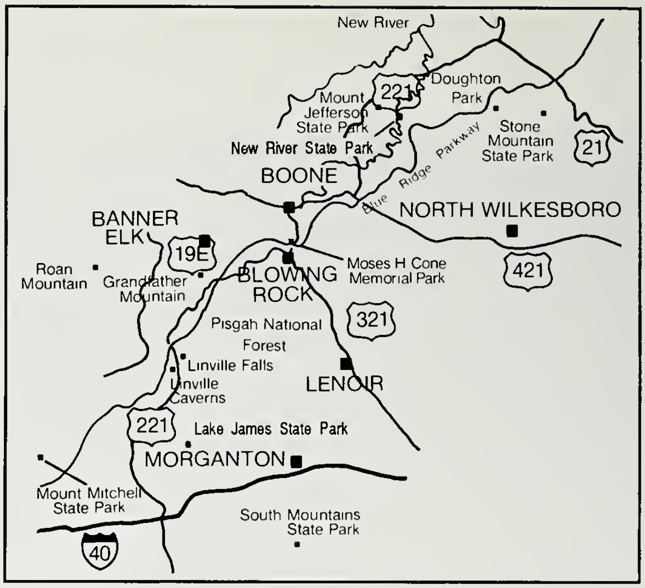


GEOLOGIC BELTS AND MAJOR STRUCTURES IN NORTH CAROLINA

Mountain Parks

MOUNT JEFFERSON STATE PARK

Mount Jefferson State Park is in southeastern Ashe County. The park, established in 1956, includes 541 acres of forest trees, shrubs and wildflowers that make it a naturalist's paradise.



GEOLOGY

Mount Jefferson State Park is located in the southern Blue Ridge Highlands at its northeastern boundary with the New River Plateau. Mount Jefferson is an isolated northwest-trending mountain that reaches a maximum elevation of 4,684 feet. It rises at least 1,600 feet above the level of the nearby stream valleys.

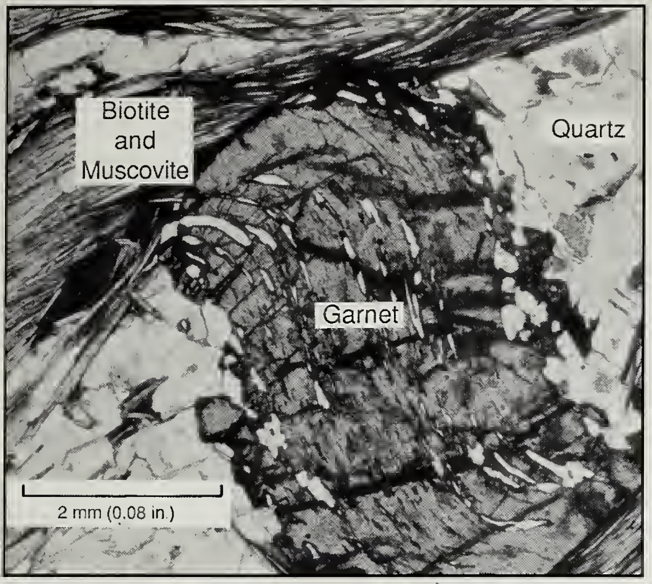
Amphibolite and ***gneiss*** of the ***Ashe Metamorphic Suite*** underlie most of Mount Jefferson. These rocks were originally deposited 600 to 800 million years ago in a trough or basin in the floor of an ancient sea. Some material was washed into the basin from the surrounding land areas, but other material was deposited as volcanic debris from now extinct volcanoes. The black rock, ***amphibolite***, seen in the park today is an example of volcanic rocks that have been changed by heat and pressure, ***metamorphism***, to form metamorphic rock.

The reason Mount Jefferson is so high is difficult to explain. Amphibolite is normally not very resistant to erosion and is usually found in lower elevations. The gneisses and schists, which are in the valley here, normally have a higher quartz content and are more resistant to erosion. It has been suggested that the gneisses and schists in this area are thinner than normal, making them mechanically weaker and so eroding more easily. The topography is also controlled by ***joint*** and ***fracture*** patterns in the area.

VISTAS AND TRAILS

The ***first overlook*** past the park office on State Road 1152 (leading to the Forest Service tower) presents an excellent panoramic view of the northern part of the Southern Blue Ridge Highlands. To the south and in the far distance, the lofty Black Mountains appear to the west of the closer and jagged spine of Grandfather Mountain. The Black Mountains are the highest mountains in eastern North America with elevations of up to 6,684 feet, on Mount Mitchell. Roan Mountain, with an elevation of 6,285 feet, is also visible in the distant southwest. To the near west is Bluff Mountain (5,100 feet) and Paddy Mountain (4,331 feet). Phoenix Mountain (4,710 feet) and Little Phoenix Mountain (3,873 feet) are to the north and are also underlain by amphibolite. White Top Mountain (5,344 feet) and Mount Rogers (5,729 feet) are visible to the distant northwest.

The ***second overlook*** on State Road 1152 provides magnificent panoramic views also. This overlook is perched upon a very steep rock outcrop of amphibolite. The outcrop and nearby road cut are excellent places to examine closely the amphibolite of the Ashe Metamorphic Suite. The outcrop is steep and somewhat dangerous so ***visitors should be careful!*** The amphibolite is distinctly layered or ***foliated***. ***Differential weathering***, where some minerals are weathering faster than others, is visible. Resistant layers of the minerals ***epidote*** and ***quartz*** stand a few inches above the less resistant ***amphibole*** and ***feldspar*** layers.



Photomicrograph of muscovite-biotite schist. Geologists cut paper-thin slices of rock to study minerals with a petrographic microscope. This thin section shows a spiral-shaped garnet. During metamorphism, the garnet deformed as it grew. Mica minerals, muscovite and biotite, are aligned parallel to each other and give the rock a foliation. This mineral alignment also occurred during metamorphism.

Approximately 750 feet from the parking lot along the trail to the fire tower is the geological contact between amphibolite and a layer of gneiss. The gneiss layer is 700 to 1,000 feet thick and is more resistant to weathering than is the amphibolite. This gneiss underlies the fire tower and its resistance to erosion may be the main reason the peak is higher than the remainder of the ridge.

The ***Rhododendron Trail***, a one-hour self-guided nature trail, travels the ridge line to ***Luther's Rock.*** From Luther's Rock there is a spectacular view to the north and east of the New River Plateau, the South Fork of the New River, the crest of the Blue Ridge Escarpment, and the Blue Ridge Parkway. Except for the first and last few stations, the trail is in amphibolite of the Ashe Metamorphic Suite. Stations 9, 10, and 11 are bare rock exposures of amphibolite and are known collectively as ***Luther's Rock***. These black-colored rocks were once ancient lava flows or volcanic rocks that have been changed by heat and pressure (***metamorphism***). They have also been folded by the forces that produced the Appalachian Mountains. These rocks, rich in iron and magnesium, influence the type of vegetation that grows in the soil here.

Mount Jefferson.

MOUNT MITCHELL STATE PARK

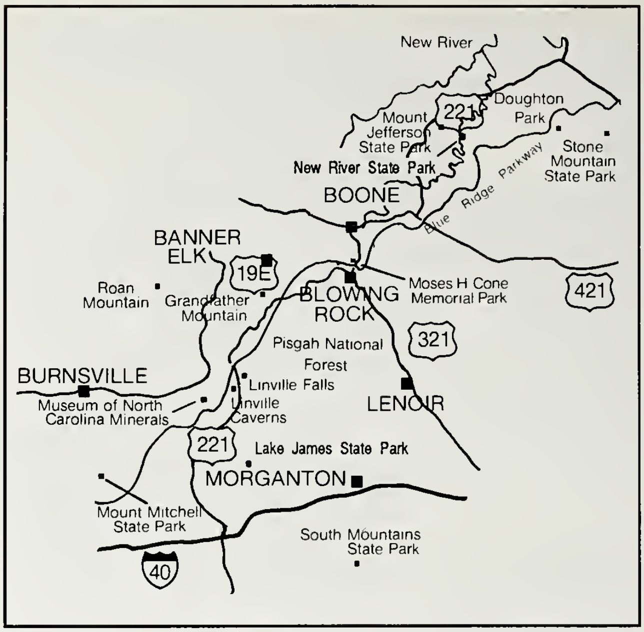
Mount Mitchell State Park is about 20 miles northeast of Asheville. The entrance to the park is at milepost 355.4 of the ***Blue Ridge Parkway***. Established in 1915 as the State's first park, it now includes 1,469 acres in the Black Mountain range. Mount Mitchell, elevation 6,684 feet, is the highest peak in the eastern United States.

Mount Mitchell was named for Dr. Elisha Mitchell, a geologist, minister, and professor, probably the first man to measure the peak, prior to 1844. He determined that the peak was higher than Mount Washington, in New Hampshire, then considered the highest peak in eastern America. Dr. Mitchell made a second trip to the mountain in 1857 to make additional measurements but fell to his death. N.C. Senator Thomas Clingman also claimed to be the first to measure the peak and this controversy has never been settled. Dr. Mitchell's grave lies near the summit of the mountain.

A visit to the summit of Mount Mitchell is rewarded with magnificent vistas in all directions. Looking east, the ***Blue Ridge front*** falls quickly into the deeply dissected Piedmont Plateau. The Blue Ridge front is a steep scarp which may have been formed by erosion. It may also simply represent the difference in base level between higher rivers in the Blue Ridge and the lower rivers in the Piedmont.

The Catawba River basin is visible in the foreground to the east. The Catawba River and the Linville River unite to form Lake James. The Catawba flows east-southeast from Lake James approximately 150 miles where it joins the Wateree River and becomes part of the Santee River basin in South Carolina.

On clear days it is possible to see beyond Lake James 80 to 90 miles to the eastern horizon. To the northeast is ***Grandfather Mountain*** and the majestic peaks of ***Table Rock*** and ***Hawksbill*** along the east side of the Linville Gorge. A mine in the ***Spruce Pine Mining District*** stands out as a white



patch to the northeast. This mining district is famous for its large ***alaskite*** deposits which yield feldspar and mica, minerals for which North Carolina annually leads the nation in production. Alaskite is white igneous rock, similar to granite, that is composed mostly of quartz, feldspar, and mica. The area is also noted for its gemstones, most notably emerald and aquamarine.

Mount Craig, named for Governor Locke Craig who was important in preserving the mountain as a state park, is the peak north of the parking area. To the west are the headwaters of the Cane River, Cane River Gap, Big Butt, and Ogle Meadow. Farther to the west, the Appalachian Mountains stretch out toward the Great Smoky Mountains. The peak to the south with two radio antennae on its summit is Clingman's Peak. South of Clingman's Peak, the Black Mountains give way to the Great Craggy Mountains.

GEOLOGY

Rocks underlying Mt. Mitchell are included in the ***Ashe Metamorphic Suite*** of rocks. These rocks were deposited approximately 600 to 800 million years ago, during ***Precambrian*** time, in an ancient sea. Sand, clay and rock fragments were washed into the sea from the surrounding land area and were mixed with material ejected from nearby volcanoes. Approximately 500 million years ago, as the landmasses moved together, the sea closed, thrusting some rocks westward over other rocks, and beginning the formation of a mountain chain. The rocks were deeply buried and then, about 430 to 480 million years ago in ***Ordovician*** time, were altered by intense heat and pressure to form metamorphic rocks called ***gneiss and schist.*** This process is called ***metamorphism.*** Additional sediments were deposited at this time, and granitic rocks were intruded. Metamorphism again affected the rocks during the late Paleozoic. During middle to late Paleozoic, as a result of shifting continental plates, North America collided with another land mass, possibly Africa, and thrust the rocks westward to form the Appalachian Mountain chain.

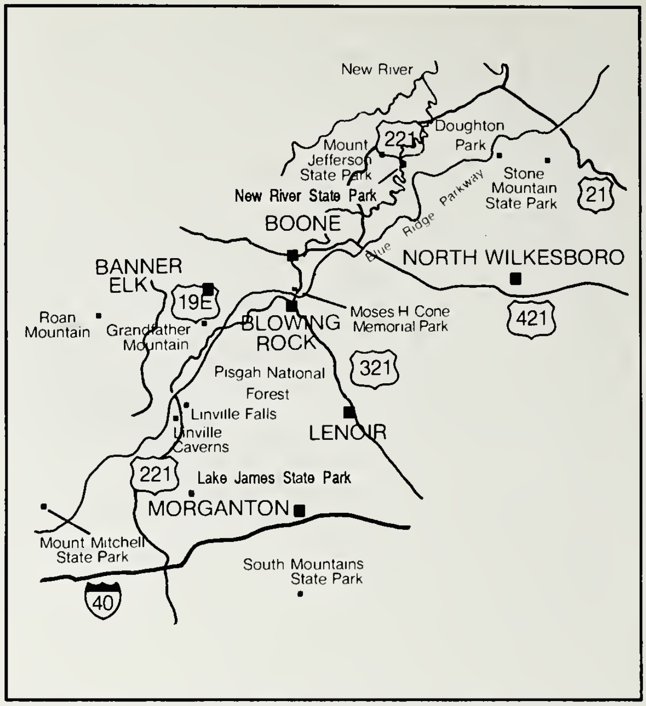
Most rocks exposed in the park are ***biotite gneiss*** or ***metagraywacke***. They were originally deposited as impure sandstones but have been metamorphosed to their present composition and texture. Primary minerals, quartz, feldspar, and biotite mica, formed through metamorphism of the original sand and clay. The minerals are concentrated into dark and light layers giving the rock a layered or ***gneissic*** appearance. The dark layers contain more biotite mica and the lighter layers contain more quartz and feldspar.

The rugged mountain landscape is the result of millions of years of gradual uplift, erosion, and slow deterioration of the rocks. The slow processes of erosion gradually wore the rocks down into sand and clay and slowly washed them down rivers into the sea. The processes of erosion continue today, slowly carrying away small particles of rock and further changing the shape of the mountain chain.

Mount Mitchell.

NEW RIVER STATE PARK

New River State Park is in northwestern North Carolina in Ashe and Alleghany Counties. The focus of the park is a 22-mile stretch of the South Fork of the New River and a 4.5-mile stretch of the New River beyond the junction of the North and South Forks of the river. This segment of the river is within both the State and Federal ***Scenic River*** systems. It is managed by the North Carolina Division of Parks and Recreation.



GEOLOGY

The park is in the New River Plateau of the Blue Ridge physiographic province. The plateau has relatively low relief, with the average relief approximately 600 feet. Major streams cross the plateau in sinuous courses and form exaggerated ***meanders*** that have long, straight reaches. Meanders are a series of regular curves or bends in the course of a river. The streams flow northwest at right angles to the trend of the bedrock.

Rocks that underlie New River State Park belong to two major geologic units found in the western part of the State. The oldest unit is ***biotite granitic gneiss*** of the ***Elk Park Plutonic Group.*** It represents some of the most ancient rocks found in the Appalachians, over one billion years old. The second major rock unit includes ***gneiss*** and ***schist*** of the ***Ashe Metamorphic Suite.***

The biotite granitic gneiss originally formed as large granite bodies that solidified from hot, molten magma in the cores of ancient mountains. The ancient mountains eroded away long ago. A small portion of the biotite granitic gneiss probably formed from sediments that were deposited in a basin or sea. The igneous and sedimentary rocks have been changed in appearance by temperature and pressure, a process called ***metamorphism.***

The gneisses and schists of the ***Ashe Metamorphic Suite*** formed where sediment washed into a sea. At the same time, volcanoes were active nearby, and volcanic debris also washed into the sea. This layered sequence of material was then buried, metamorphosed, deformed, and then exposed at the Earth's surface through uplift and erosion. Dark-colored, iron- and magnesium-rich rocks called ***ultramafic rocks*** are also interlayered with the gneiss.

The South Fork of the New River flows across an area where, during the formation of the Appalachian Mountains, the rocks were gently arched downward. This downfold in the rocks is called the ***Ararat River Synclinorium.*** The large fold controls the outcrop pattern of rocks along the South Fork of the New River.

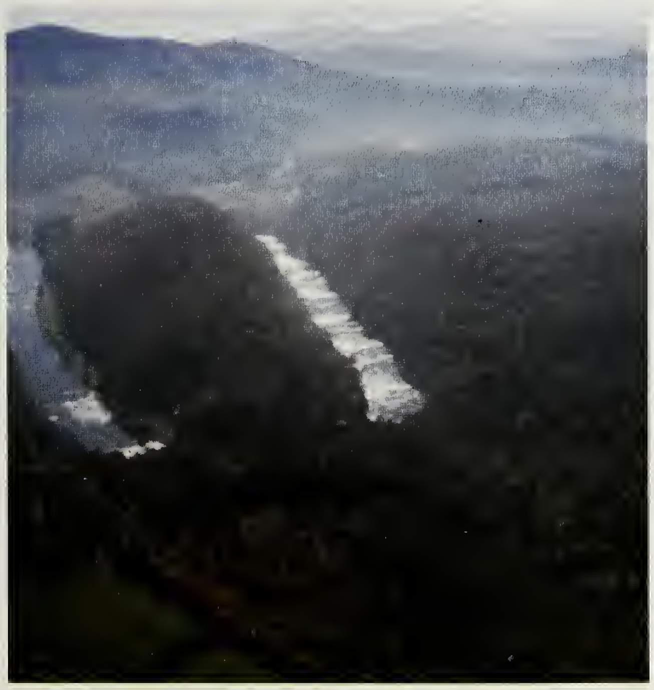
GEOLOGIC FEATURES

Many geologic features and processes can be observed along the New River. These include: ***rapids***, ***potholes***, ***floodplains***, ***meanders***, ***erosion***, ***transportation***, and ***deposition.***

Rapids along the river are the result of ***differential erosion***, where softer, weaker rocks are rapidly worn away and harder, more resistant rocks remain to form rapids or waterfalls. Along the New River, quartz-rich gneisses are usually the most resistant layers and form many of the rapids.

The tight ***meandering*** nature of the New River is unusual for a stream with such a moderate gradient or flow. It can be attributed to a time in the geologic past when the South Fork was flowing much more gently. The area was then uplifted and tilted, causing the river to cut deeper into the rocks. Meanders result from the flow of water through a channel. They are the form by which, in making a turn, a river experiences the least flow resistance, does the least work, and releases energy the most uniformly along its course. Meanders change position almost continually.

The New River valley provides an excellent opportunity to study stream channel development. The river cuts steep slopes on the outsides of bends where the velocity of the water flow is the greatest. Deposition occurs on the insides of bends where the stream velocity is the least. ***Potholes***, circular, elliptical holes in the rocks, often develop where bedrock is exposed in the bed of the river. They begin as shallow depressions where swirling, turbulent water drives sand, pebbles and even cobbles round and round the depression. This continued abrasion wears the potholes even deeper, as if the bedrock is being bored by a giant drill.



The meandering course of the New River.

ACCESS AREAS

The ***Wagoner Road*** access area (Site #1) is on a narrow floodplain opposite the largest ***sand bar*** (island) within the channel of the river. This island formed as the flow of the river slowed and could no longer carry the heavier particles. The larger sand and gravel particles then dropped to the river bottom. Downstream at the northern end of the canoe access and camping area, a resistant layer of gneiss is exposed.

Site #3 is for river travelers and has no road access. The site is on the northwest side of a large meander. It is on the inside or depositional side of the meander. On the opposite side of the river, the valley wall is much steeper and, in places, is a rock cliff. The cliff is composed of ***amphibolite***, a dark rock containing hornblende and plagioclase feldspar, and ***gneiss*** of the Ashe Metamorphic Suite.

Site #5 is a primitive camping area across the river from an area known locally as ***the bluffs***. ***The bluffs*** is a granite wall that rises 200 feet above the river level. The granite is approximately 1.1 billion years old. The camp site is on the inside or ***depositional side*** of the river, but the bluffs are on the outside or ***cut bank*** where the river flow is greater. On the northeast side of the picnic area is a large sand bar that formed where the river flow began to slow. The river could no longer transport the larger particles and they fell to the river bottom, gradually building the bar.

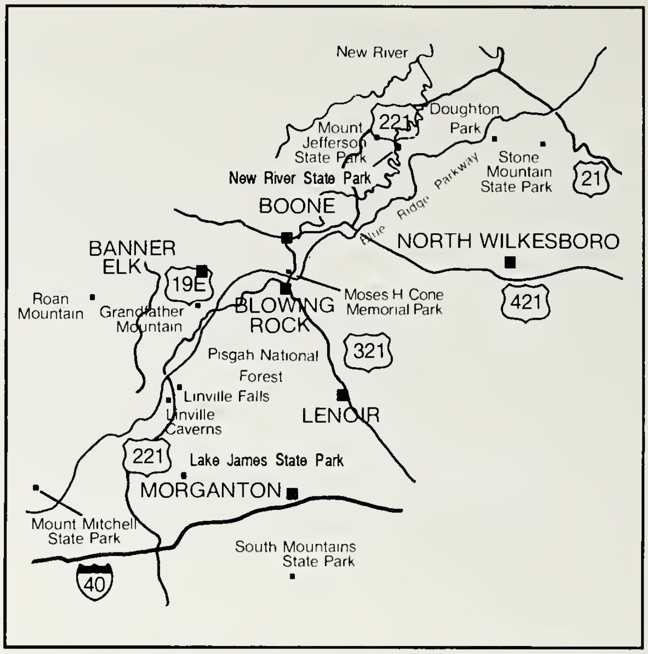
STONE MOUNTAIN STATE PARK

Located in Wilkes and southeastern Alleghany counties, the park is approximately 17 miles northwest of North Wilkesboro and 9 miles southeast of Sparta. Established in 1968 with about 2,100 acres, it now contains about 11,000 acres.

Stone Mountain State Park is dominated by a granitic dome which can be seen for many miles when approaching the park. The steep sides of the granite mass attract rock climbers from many areas. The many miles of park trails take the visitor past swiftly cascading waterfalls rushing over granite ledges into cool deep pools. The streams spread out across smooth, slippery water-polished surfaces ideal for water sliding. Hawks and birds of prey rise on thermals, rising currents of warm air, where the exposed granitic rock is heated by the sun. ***Beauty Falls*** (also known as Stone Mountain Falls or Little Falls) is formed where Big Sandy Creek plunges over a granitic face over 200 feet high.

The granitic mountain dominating the park's skyline has an elevation of 2,305 feet. It rises almost 700 feet above the valley floor.

Stone Mountain, an exfoliation dome.



GEOLOGY

There are two main rock units in this park. Biotite gneiss, the oldest rock unit in the park, formed from muddy and sandy sediments, and from volcanic lava flows and ash that were deposited between 500 to 600 million years ago. These sediments were buried and compressed to form rocks; eventually, they were exposed at the land surface by the processes that make mountains. Geologists refer to these rocks as the ***Alligator Back Formation***.

Stone Mountain, **Wolf Mountain**, and the other high areas of the park are composed of a second rock unit, similar to granite. This rock unit is about 390 million years old. The granite formed from ***magma***, molten rock, several miles deep in the earth. Eventually, the magma cooled and crystallized, and formed the granitic body.

About 200 million years ago, erosion began stripping away some of the overlying rocks. As the miles of rock overlying the granitic rock were removed by erosion, the release in pressure caused the rock mass to expand upward. As it expanded upward, lines of fractures developed parallel to the present ground surface, and slabs of rock, ***exfoliation sheets***, developed. These curved exfoliation sheets help control the mountain's dome shape. Stone Mountain is an ***exfoliation dome.***

Once uncovered, granitic rocks are more resistant to erosion than the metamorphic rocks which they intruded. Thus, Stone Mountain Creek flows along the curved shape of Stone Mountain at its north end until it turns and cuts through the granite along a plane or surface of weakness in the granitic rock.

Wolfe Rock, ***Cedar Rock***, ***Little Stone Mountain***, ***Buzzard Rock***, ***First Flat Rock***, and ***Hitching Rock*** are bare rock exposures that give this park its distinctive appearance. Birds of prey are commonly seen riding the thermals from the heating of these bare granite surfaces.

Indian Den Rock and ***Rock House*** are natural rock shelters formed from fallen granite boulders that touch. The open spaces formed under these boulders are large enough to provide the park visitor with shelter from a sudden rain shower.

Along the park's trails, smaller features of geologic interest can be seen; these include ***weathering pits***, ***joints***, and ***xenoliths***.

Weathering pits are irregularly rounded depressions in the granitic rock. Chemical and physical processes are responsible for their formation. Weathering pits begin to form when some minerals weather more rapidly than others. Water collects in the resulting spaces in the rock surface; water continues to collect in these depressions and they slowly enlarge, merging with others, to form the distinctive "pock-marked" surface. The plant communities and soils that eventually developed on the granite began when lichens and moss colonies established a "toe hold" in these weathering pits. These plants provided organic acids which helped to decompose the minerals and produce a thin soil horizon. Eventually, grasses and flowers flourished, and finally, soils became sufficiently thick to support pine and hardwood communities.

Joints are fractures in the rock along which there has been no movement. Several different orientations of joints are present in the granitic rocks at Stone Mountain State Park. Some joints developed during exfoliation parallel to the topography of the mountains. The curved granitic slabs lying loosely on top of the rock pavements at Stone Mountain are the result of sheet joints. ***Sheet joints*** develop parallel to the ground's surface as overlying rocks are removed and the granite expands. Other more steeply inclined joints occur within the granite mass and are the cracks used by climbers to ascend Stone Mountain. Joints and intersecting joints create the spectacular ***Great Arch*** and other climbing routes such as the ***Great White Way***, ***Mercury's Lead***, and others.

Xenoliths are the remains of older metamorphic rocks which were invaded by the molten granitic material. Where the hot, molten material did not dissolve all of the blocks of the surrounding rock, xenoliths formed. The xenoliths are composed of biotite gneiss and amphibolite; they appear as the dark clots in the granite.

A weathering pit in granite.

OTHER STATE PARKS

Boone's Cave State Park is in the Piedmont physiographic province approximately 14 miles west of Lexington. It is the legendary site of Daniel Boone's hide-out on the east side of the Yadkin River. The cave extends for about 80 feet into granitic rock, referred to as the ***Churchland Pluton***. This granite formed 280 million years ago and is interesting because of the large feldspar crystals it contains. The crystals, in places 2 to 3 inches across, weather out on the surface of the ground. When an igneous rock contains large crystals surrounded by smaller crystals, it is called a ***porphyry*** or, in this instance, a ***porphyritic granite***. This type of texture gives geologists clues about how the rock formed.

Goose Creek State Park is in Beaufort County on the north bank of the Pamlico River between Washington and Bath. It is in the flat, low-lying ***tidewater*** region of the Coastal Plain. In this portion of the Pamlico River, fresh water from the river is mixed with salt water from the Pamlico Sound to form ***brackish water***, typical of Coastal Plain estuaries. The park is underlain by surface sand and clay which covers the older Coastal Plain formations. The park is a good place to observe marsh and swamp environments.

The 1987 General Assembly appropriated funds to establish ***Lake James State Park***. The site is 13 miles west of Morganton on the south shore of Lake James, built in 1919 by Duke Power Company. The park lies within the Inner Piedmont geologic province. Rock types are mostly ***muscovite (white mica) schist*** and ***biotite (black mica) gneiss***. Mica flakes in the soil reflect the large amount of mica in the rocks beneath the surface of the ground.

Theodore Roosevelt Natural Area is 7 miles west of Atlantic Beach on one of the state's barrier islands, Bogue Island. The natural area was donated to the state by the 26th President of the United States. It is located around the North Carolina Marine Resources Center, and represents brackish marsh and maritime forest environments. The main park trail crosses a forested ridge and swale topography.

Waynesboro State Park is off US 117 Bypass in Goldsboro. It is on the Neuse River and is set in a typical Coastal Plain river environment.

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The geologic descriptions are a combined effort of the North Carolina Geological Survey staff geologists. Authors of the guides to individual parks are listed in the Contents. The editor accepts responsibility for any errors which occured during editing in an attempt to achieve uniformity. The general geology (page 5) was modified from the ***Guide to Geologic and Other Natural Resources Points of Interest Along Interstate 40*** by Edward R. Burt, III.

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GLOSSARY*

A

absolute age - The age in years, commonly based on radiometric dating techniques.

Alligator Back Formation - A mappable unit of rocks consisting primarily of gneiss, schist, amphibolite, and minor amounts of quartzite and marble which are exposed along the Blue Ridge escarpment from Wilkes County, N.C., to Patrick County, Virginia.

artesian - An adjective referring to ground water confined under hydrostatic pressure.

amphibolite - A metamorphic rock consisting mainly of amphibole and plagioclase feldspar with little or no quartz.

anticlinorium - A composite anticlinal structure of regional extent composed of lesser folds.

argillite - A compact rock, derived either from mudstone or shale, that has undergone a somewhat higher degree of induration than mudstone or shale but is less clearly laminated than shale and without its fissility, and that lacks the distnctive cleavage of slate.

Ashe Metamorphic Suite - Fine-grained, thinly layered sulfur-rich, biotite-muscovite gneiss, interlayered with varying amounts of mica schist and amphibolite in central Ashe County.

B

barrier island - A long, narrow coastal sandy island, representing a broadened barrier beach that is above high tide and parallel to the shore, and that commonly has dunes, vegetated zones, and swampy terranes extending lagoonward from the beach.

basalt - A general term for dark-colored mafic igneous rocks, commonly extrusive but locally intrusive, composed chiefly of calcic plagioclase and clinopyroxene; the fine grained equivalent of gabbro.

basin - A low geographic area in which sediments may accumulate.

Battleground Formation - A mappable unit of rocks in the Kings Mountain belt consisting primarily of sericite schist and also containing interlayered metavolcanic and metasedimentary rocks

bedding - The arrangement of a sedimentary rock in beds or layers of varying thickness and character.

bedding plane - A planar or nearly planar bedding surface that visibly separates each successive layer of stratified rock from the preceding or following layer.

bedrock - A general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material.

biotite - A black, dark brown, or dark-green iron- and magnesium-bearing mineral of the mica group.

blowout - A general term for a small saucer-, cup-, or trough-shaped hollow or depression formed by wind erosion on a pre-existing dune or other sand deposit.

bog - Waterlogged, spongy ground, consisting primarily of mosses, containing acidic, decaying vegetation that may develop into peat.

C

calcite - Calcium carbonate in its hexagonal crystalline form.

Cambrian - The oldest period of the Paleozoic Era, lasting from 570 to 500 million years ago.

cape - An extensive, somewhat rounded irregularity of land jutting out from the coast into a large body of water.

Cape Fear Arch - A subsurface northwest-southeast-trending anticlinal structure composed of pre-Cretaceous rocks that plunge gently to the southeast. The arch is buried beneath Coastal Plain sediments in parts of Bladen, Columbus, and Brunswick counties, N.C.

cast - Secondary rock or mineral material that fills a natural mold.

Cenozoic - The youngest and present geologic era, which started about 65 million years ago.

clast - An individual constituent, grain, or fragment of a sediment or rock, produced by the mechanical weathering of a larger rock mass.

Cleavage - The property or tendency of a rock to split along secondary, aligned fractures or other closely spaced, planar structures or textures, produced by deformation or metamorphism.

Coastal Plain - The generally flat land area between the ocean and the hills of the Piedmont, blanketed by Mesozoic and Cenozoic sediments.

* Definitions are modified, in part, from the *Glossary of Geology*, (1980) American Geological Institute.

concordant - A contact between an igneous intrusion and the country rock that parallels the foliation or bedding planes of the latter.

conglomerate - A sedimentary rock consisting of rounded, waterworn fragments of rock or pebbles cemented together by another mineral substance.

continental shelf - The gently sloping, shallowly submerged marginal zone of the continents extending from the shore to an abrupt increase in bottom inclination.

coquina - A sedimentary rock composed almost entirely of cemented mollusk shells and other invertebrate fragments.

Coriolis force - The tendency of particles in motion on the Earth's surface to be deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

creep - The slow, more or less continuous downslope movement of mineral, rock, and soil particles under gravitational stresses.

Cretaceous - The third and youngest of the three Mesozoic periods, lasting from approximately 141 to 65 million years ago.

cross-beds - Sedimentary layers inclined at an angle to the main planes of stratification.

crystalline - A general term used to refer to igneous and metamorphic rocks.

D

deflation - The sorting out, lifting, and removal of loose, dry fine grained particles by the turbulent eddy action of the wind. A form of wind erosion.

delta - The low, nearly flat, alluvial tract of land at or near the mouth of a river, commonly forming a triangular or fan-shaped plain of considerable area, crossed by many distributaries of the main river, perhaps extending beyond the general trend of the coast, and resulting from the accumulation of sediment supplied by the river in such quantities that it is not removed by the tides, waves, and currents.

deltaic — Pertaining to a delta.

Devonian - A period of the Paleozoic era, spanning the time between 400 and 345 million years ago.

diabase - A fine-grained, black intrusive rock composed principally of labradorite feldspar and pyroxene.

differential weathering - Weathering that occurs at different rates, as a result of variations in composition and resistance of a rock or differences in intensity of weathering, and usually resulting in an uneven surface where more resistant material stands higher or protrudes above softer or less resistant parts.

dike - A tabular igneous intrusion that cuts across the bedding or foliation of the surrounding rock.

dinosaur - Any member of the extinct reptile orders Saurischia and Ornithischia.

diorite - A plutonic rock intermediate in composition between felsic and mafic, characteristically composed of dark-colored amphibole, sodium-rich plagioclase, pyroxene, and sometimes a small amount of quartz.

discordant - A contact between and igneous intrusion and the surrounding rock that is not parallel to the bedding or foliation planes of the latter.

dissected - The process of erosion by which a relatively even topographic surface is gradually sculptured or destroyed by the formation of gullies, ravines, canyons, or other kinds of valleys.

E

Eocene - The second oldest epoch of the Paleogene Period, lasting approximately from 55 to 37 million years ago.

eolian - Pertaining to the wind.

eon - The largest geologic time unit, consisting of eras and their subordinate time units.

epidote - A yellowish-green, pistachio-green, or blackish-green mineral.

epoch - A geologic time unit of intermediate rank between periods and ages.

era - A geologic time unit of rank between eon and period.

erosion - The general process or group of processes whereby the materials of the Earth's crust are loosened, dissolved or worn away, and simultaneously moved from one place to another, by natural agencies.

escarpment - A long, more or less continuous cliff or relatively steep slope facing in one general direction, breaking the continuity of the land by separating two level or gently sloping surfaces, and produced by erosion or by faulting.

eustasy - The world wide sea-level regime and its fluctuations caused by variations in the volume of the oceans, and variations in the quantity of sea water caused by continental ice cap fluctuations.

exfoliation - The process by which plates, or shells of rock, from less than a centimeter to several meters in thickness, are successively spalled or stripped from the bare surface of a large rock mass.

F

facies - The aspect, appearance and characteristics of a rock unit, usually reflecting the conditions of its origin; the environment in which a rock was formed.

fall line - An imaginary line or narrow zone connecting the waterfalls on several adjacent, near-parallel rivers, marking the points where these rivers make a sudden descent from an upland to a lowland, as at the edge of a plateau.

fanglomerate - A sedimentary rock consisting of slightly water-worn, heterogeneous fragments of all sizes, deposited in an alluvial fan and later cemented into a firm rock.

feldspar — Any of a group of abundant, rock-forming minerals occurring principally in igneous and metamorphic rocks, and consisting of silicates of aluminum with potassium, sodium, calcium, and, rarely, barium.

felsic - An adjective applied to an igneous rock having abundant light-colored minerals, most commonly feldspar and quartz.

fissure - A surface of fracture or a crack in a rock along which there is a distinct separation.

float - A general term for isolated, displaced fragments of a rock, especially on a hillside below an outcropping ledge or vein.

flow - A lava flow.

formation - A formally named stratigraphic unit consisting of a distinct, usually tabular body of rock that is mappable at the Earth's surface or traceable in the subsurface.

fossil - Any remain, impression, or trace of a plant or animal from a former geologic age.

fulgurite - An irregular, glassy, often tubular or rod-like structure or crust produced by the fusion of loose sand by lightning, and found esp. on mountain tops or in dune areas of deserts or lake shores.

G

gabbro - A group of dark-colored, mafic intrusive igneous rocks composed principally of calcic plagioclase and clinopyroxene, with or without olivine and orthopyroxene. It is the approximate intrusive equivalent of a basalt.

geologic column - The sequence of rocks in a designated part of the Earth.

geomorphic - Pertaining to the form of the Earth or of its surface features.

gneiss - A foliated rock formed by regional metamorphism, in which bands or layers of granular minerals alternate with bands or layers in which minerals having flaky or elongate prismatic habits predominate.

granite - A plutonic rock in which quartz consitiutes 10 to 50 percent of the felsic components and in which the alkali feldspar/total feldspar ratio is generally restricted to the range of 65 to 90 percent.

groin - A low, narrow jetty constructed of timber, stone, concrete, or steel, usually extending roughly perpendicular to the shoreline, designed to protect the shore from erosion by currents, tides, or waves, or to trap sand and littoral drift for the purpose of building or making a beach.

H

Holocene - The youngest and present epoch of the Quaternary period, beginning approximately 10,000 years ago.

hornblende - The most common mineral of the amphibole group. It is commonly black, dark green, or brown, and occurs as distinct monoclinic crystals or in columnar, fibrous, or granular forms.

hydrothermal - Of or pertaining to hot water, to the action of hot water, or to the products of this action.

I

Ice Age - The Pleistocene Epoch, characterized by extensive continental and polar glaciation.

ice rafting - The transportation of rock fragments of all sizes on or within icebergs, icefloes, or other forms of floating ice.

ice sheet - A glacier of considerable thickness and more than 19,000 sq mi in area, forming a continuous cover of ice and snow over a land surface, spreading out in all directions and not confined by the underlying topography; a continental glacier.

igneous - Formed by solidification from a molten or partially molten state.

indurated - Said of a rock or soil hardened or consolidated by pressure, cementation, or heat.

inlet - A small, narrow opening, recess, or indentation, or other entrance into a coastline or a shore of a lake or river, through which water penetrates into the land.

intrusive - An adjective pertaining to intrusion, the process of emplacement of magma in pre-existing rock; magmatic activity; also the igneous rock mass so formed within the surrounding rock.

J

jetty - An engineering structure extending out from the shore into a body of water, designed to direct and confine the current or tide, to protect a harbor, to induce scouring, or to prevent shoaling of a navigable passage by littoral materials.

joint - A surface of fracture or parting in a rock, without displacement; the surface is usually plane and often occurs with parallel joints to form part of a joint set.

Jurassic - The middle period of the Mesozoic Era, lasting approximately from 195 to 141 million years ago.

K

kyanite - A blue or light-green mineral that occurs as long, thin, bladed crystals and crystalline aggregates in schist and gneiss.

L

lagoon - A shallow stretch of seawater, such as a sound, channel, bay, or saltwater lake, near or communicating with the sea and partly or completely separated from it by a low, narrow, elongate strip of land, such as a reef, barrier island, sandbank, or spit.

lahar - A mudflow composed chiefly of volcaniclastic materials on the flank of a volcano.

laminated - In thin layers.

leeward - Said of the side or slope sheltered or located away from the wind; downwind.

lens - A geological deposit bounded by converging surfaces, with at least one of them being curved, thick in the middle, and thinning out toward the edges.

lignite - An imperfectly formed coal, usually dark-brown and commonly having a woody texture; brown coal.

limestone - A sedimentary rock consisting predominantly of calcium carbonate, $CaCO_3$.

limonite - A yellow to brown, non-crystalline, hydrated iron oxide of varying composition.

lithic - Pertaining to rock.

longshore currents - An ocean current caused by the approach of waves to a coast at an angle.

M

magma - Molten matter under the Earth's crust, from which igneous rock is formed by cooling.

meander - One of a series of regular freely developing curves, bends, loops, turns, or windings in the course of a stream.

Mesozoic - The middle of three eras of the Phanerozoic Eon, lasting from about 230 to 65 million years ago.

metagraywacke - A metamorphosed dark gray firmly indurated coarse-grained sandstone that consists of poorly sorted angular to subangular grains of quartz and feldspar, with a variety of dark rock and mineral fragments embedded in a compact clayey matrix .

metamorphic rock - A rock in which great heat or pressure has altered its original composition, structure, or texture.

metamorphism - The mineral, chemical, and structural adjustment of rocks to exterior agencies such as deformation or a rise in temperature and pressure.

metasedimentary - A metamorphosed sedimentary rock.

metavolcanic - A metamorphosed volcanic rock.

micaceous - Containing any of the mica, or sheet silicate minerals.

Miocene - The older epoch of the Neogene Period, lasting from approximately 22.5 to 5 million years ago.

mold - An impression made in the surrounding earth or rock material by the exterior or interior of a fossil shell or other organic structure.

monadnock - An upstanding rock, hill, or mountain rising conspicuously above the general level of a relatively flat plane in a temperate climate, representing an isolated remnant of a former erosion cycle in a mountain region that has been largely beveled to its base level.

monazite - A yellow, brown, or reddish-brown mineral that is a principal ore of rare earths and thorium.

mud flat - A relatively level area of clay and fine silt along a shore or around an island, alternately covered and uncovered by the tide, or covered by shallow water; a muddy tidal flat.

mudstone - A clayey sedimentary rock of nearly uniform texture throughout, with little or no lamination.

muscovite - A colorless to yellowish to pale brown mineral of the mica group.

mylonite - A compact, chert-like rock without cleavage, but with a streaky or banded structure, formed by the extreme granulation and shearing of rocks that have been pulverized and rolled during overthrusting or intense metamorphism.

O

Oligocene - The youngest epoch of the Paleogene Period, lasting from approximately 37 to 22.5 million years ago.

organic - Pertaining to or related to a compound containing carbon, especially as an essential component.

outcrop - The part of a geologic formation which appears at the surface of the earth.

overwash - A mass of water representing the part of the uprush that runs over the berm crest (or other structure) and that does not flow directly back to the sea or lake.

P

Paleocene - The oldest epoch of the Tertiary Period, lasting from approximately 65 to 55 million years ago.

Paleogene -The Cenozoic Period which includes the Paleocene, Eocene and Oligocene epochs.

Paleozoic - The first era of the Phanerozoic Eon, lasting from approximately 570 to 230 million years ago.

peat - An unconsolidated deposit of semicarbonized plant remains in a water saturated environment, such as a bog or fen, and of persistently high moisture content (at least 75%). It is considered an early stage in the development of coal .

period - A geologic time unit of rank between era and epoch.

Permian - The last period of the Paleozoic era, thought to have covered a span of time between 280 and 225 million years ago.

Phanerozoic - The current eon which started approximately 570 million years ago, and consists of the Paleozoic, Mesozoic and Cenozoic Eras.

phyllite - A metamorphosed rock, intermediate in grade between slate and mica schist. Minute crystals of sericite and chlorite impart a silky sheen to the surfaces of cleavage.

phyllonite - A rock that resembles phyllite but that is formed by mechanical degredation of initially coarser rocks.

Piedmont - The low platform in the eastern United States extending eastward from the Appalachian and Blue Ridge Mountains to the Coastal Plain, and northward from Alabama to New Jersey.

Pleistocene - The older of two epochs of the Quaternary Period, lasting approximately from 1.6 million to 10,000 years ago.

Pliocene - The younger of the two epochs of the Neogene Period, lasting from approximately 5 to 1.6 million years ago.

plutonic - Of deep igneous or magmatic origin.

pocosin - A local term along the Atlantic coastal plain south of Virginia for a swamp or marsh on a flat upland, bordering on or near the sea, in many cases enclosing knobs or hummocks.

porphyry - An igneous rock of any composition that contains conspicuous crystals, larger than the surrounding crystals, surrounded by finer grained crystals.

pothole - A smooth, bowl-shaped or cylindrical hollow, generally deeper than wide, formed in the rocky bed of a stream by the grinding action of a stone or stones, or of coarse sediment, whirled around and kept in motion by the force of the stream current in a given spot.

Precambrian - All geologic time prior to the beginning of the Cambrian Period.

pyrite - A mineral, iron sulfide, FeS_2, also called fool's gold, with the same composition as marcasite but with a different crystalline form.

Proterozoic - An eon in geologic time which started approximately 2,500 million years ago and lasted until 570 million years ago.

pyroclastic - Pertaining to clastic rock material formed by volcanic explosion or aerial expulsion from a volcanic vent.

Q

quartz - A hard, crystalline, vitreous mineral consisting of silicon dioxide, SiO_2.

quartzite - A granular metamorphic rock consisting essentially of quartz in interlocking grains.

quartzose - Containing quartz.

Quaternary - The third and present period of the Cenozoic Era, which began approximately 1.6 million years ago.

R

radiometric dating techniques - Any of several methods of determining the age of rocks or minerals by measuring the ratio of their radioactive atoms and their decay products.

rapids - A swift, turbulent flow or current of water through an area of rock or outcrop that restricts the flow of water.

regression - Seaward retreat of the shoreline through geologic time.

relative age - A geologic age based on relative position in a sequence of rock units, or based on presumed position in a stratigraphic sequence.

relief - The vertical difference in elevation between the hilltops or mountain summits and the lowlands or valleys of a given region.

rhyolite - A group of extrusive igneous rocks, typically porphyritic and with flow structure, with phenocrysts of quartz and alkali feldspar in a glassy or very fine-grained groundmass. The extrusive equivalent of granite.

rift valley - A valley that has developed along a long, narrow continental trough that is bounded by faults.

S

salt marsh - Flat, poorly drained land that is subject to periodic or occasional overflow by salt water, containing water that is brackish to strongly saline, and usually covered with a thick mat of grassy halophytic plants.

sandstone - A sedimentary rock composed chiefly of sand-sized quartz grains cemented by calcium carbonate, silica, or other materials.

saprolite - A soft, earthy, typically clay-rich, thoroughly decomposed rock, formed in place by chemical weathering of igneous, metamorphic, or sedimentary rocks. Saprolite is characterized by the preservation of structures that were present in the unweathered rock.

scarp - A cliff face produced by erosion or faulting.

schist - A strongly foliated metamorphic rock that can be easily split into thin flakes or slabs because of the well developed parallelism of more than 50% of the minerals present, particularly flat or elongate minerals, such as mica and hornblende.

sediment - Solid fragmental material such as sand, gravel and clay, plus other transported fragments that settle to the bottom of a body of water.

sedimentary rock - A rock formed from sediment.

sedimentation - The process of accumulation of sediment.

sericite - A white, fine-grained potassium mica occurring in small scales and flakes as an alteration product of various minerals; very similar to fine-grained muscovite.

shale - A fissile sedimentary rock composed of laminated layers of clay-like, fine-grained sediments.

shell limestone - A limestone containing the remains of shells or shell molds and casts.

silica - Silicon dioxide, SiO_2.

sillimanite - A brown, gray, pale-green, or white mineral that occurs in long, slender needlelike crystals.

silicified - Cemented by or replaced with silica.

siltstone - A sedimentary rock composed of silt-sized sedimentary particles.

sinkhole - A natural depression in a land surface communicating with a subterranean passage, generally occurring in limestone regions and formed by dissolution or by collapse of a cavern roof.

spherulite - A rounded or spherical mass of needle-like crystals, commonly feldspar, radiating from a central point. Spherulites may range in size from microscopic to several centimeters in diameter.

strata - Plural of "stratum."

stratigraphy - The science of rock strata.

stratum - A layer of sedimentary rock, visually separable from other layers above and below.

subgenus - A taxonomic rank below genus and above species.

submarine - On the ocean floor.

surficial - Of, pertaining to, or occurring on the Earth's surface.

swash zone - The sloping part of the beach that is alternately covered and uncovered by the uprush of waves, and where the longshore movement of water occurs in a zigzag manner.

T

tectonism - A general term for all movement of the crust produced by tectonic processes, including the formation of ocean basins, continents, plateaus, and mountain ranges.

tidal channel - A channel followed by tidal currents.

tidal flat - An extensive, almost horizontal, marshy or barren area of unconsolidated sand and mud, which is alternately covered and uncovered by the tide.

tidal delta - A delta formed at the mouth of a tidal inlet.

transgression - Landward advance of the shore line through geologic time.

Triassic - The oldest period of the Mesozoic Era, lasting from approximately 230 to 195 million years ago.

Triassic basin - A long, narrow trough filled with Triassic age sedimentary rocks.

tuff - A general term for all unconsolidated rocks (pyroclastic) formed by volcanic explosion or aerial expulsion from a volcanic vent.

tuff breccia - A pyroclastic rock consisting of more or less equal amounts of ash, and larger fragments.

U

unconformity - A surface of erosion or non-deposition in the sedimentary rock record.

ultramafic -An igneous rock composed chiefly of dark-colored iron- and magnesium-rich minerals.

V

vein - A thin sheet-like igneous intrusion into a fissure.

volcanic - Pertaining to the activities, structures, or rock types of a volcano.

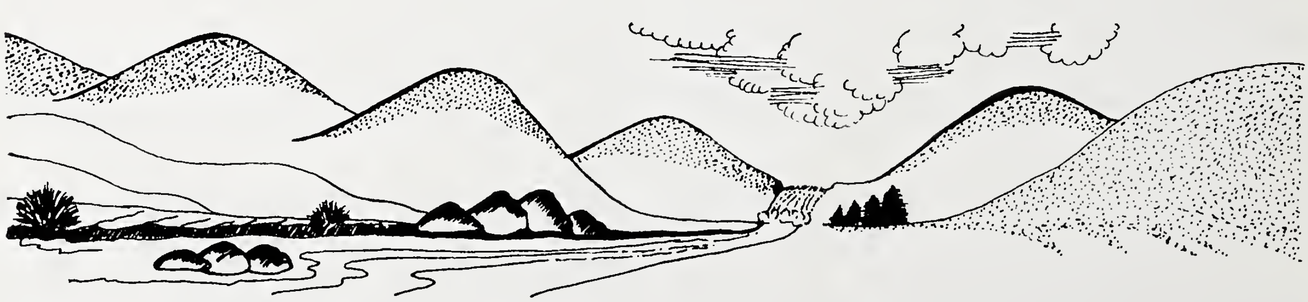
W

weathering - The physical disintegration and chemical decomposition of rock at the Earth's surface.

weathering pit - A shallow depression on the flat or gently sloping summit of large exposures of granite or granitic rocks, attributed to strongly localized solvent action of impounded water.

X

xenolith - A foreign inclusion in an igneous rock.



GEOLOGICAL SURVEY SECTION

The Geological Survey Section shall by law "...make such examination, survey, and mapping of the geology, mineralogy, and topography of the state, including their industrial and economic utilization as it may consider necessary."

In carrying out its duties under this law, the Section promotes the wise conservation and use of mineral resources by industry, commerce, agriculture, and governmental agencies for the general welfare of the citizens of North Carolina.

The Section conducts a number of basic and applied research projects in environmental geology, mineral resource exploration, mineral statistics, and systematic geologic mapping. Services constitute a major portion of the Section's activities and include identifying rock and mineral samples submitted by the citizens of the State and providing consulting services and specially prepared reports to agencies that require geological information.

The Geological Survey Section publishes results of research in a series of Bulletins, Economic Papers, Information Circulars, Educational Series, Geologic Maps, and Special Publications. For a complete list of publications or more information about the Section please write: Geological Survey Section, P.O. Box 27687, Raleigh, North Carolina 27611. The telephone number is: (919) 733-2423.

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NORTH CAROLINA GEOLOGICAL SURVEY SECTION

DIVISION OF LAND RESOURCES

DEPARTMENT OF NATURAL RESOURCES
AND COMMUNITY DEVELOPMENT